AN EXAMINATION OF ARCHIVAL GEOPHYSICAL DATA FROM THE SYDNEY COALFIELD, NOVA SCOTIA TO IDENTIFY SEAFLOOR LONGWALL SUBSIDENCE PROFILES

SUBMITTED TO:

CAPE BRETON COAL RESEARCH LABORATORY
210 George Street
Sydney, Nova Scotia
B1P 1J3

SUBMITTED BY:

MCGREGOR GEOSCIENCE LIMITED
121 Ilsley Avenue, Unit W
Dartmouth, Nova Scotia
B3B 1S4

Submission Date:	January 1987
DSS Contract Number:	03SQ23340-6-9026
CBRCL Scientific Authority:	Tim Aston
McGregor Project Supervisor:	John Stewart
Report Written By:	Tony LaPierre
McGregor Project Number:	86-20
McGregor Document Number:	P18/322

80 pp + fig

MICROMEDIA

SUMMARY

A study of marine geophysical data from the Sydney coalfield was conducted by McGregor GeoScience Ltd. on behalf of Canada Centre for Mineral and Energy Technology (CANMET)-Energy, Mines and Resources (EMR)-Cape Breton Coal Research Laboratory. The purpose of this study was to search for evidence of seafloor subsidence caused by longwall coal mining. The geophysical track plots from three offshore surveys (NSRF - 1978; Dobrocky Seatech Ltd. - 1984 and BIO - 1985) and mineworking plans showing longwall panel positions were compiled. The geophysical records from these three surveys were then examined for seafloor troughs in the areas of longwall mining. No correlation of the seafloor profiles and longwall panels was observed. Therefore the archived geophysical data examined in this study cannot be used to evaluate subsidence. The lack of pre-mining seafloor profiles to reference against post-mining measurements has precluded the distinction of seafloor troughs and is the critically limiting factor in this study.

SOMMAIRE

Une étude de données géophysiques marines de la houillère de Sydney fut entreprise par McGregor GeoScience Ltée, dans l'intérêt du Centre Canadian de la Technologie des Minéraux et de L'Energie (CANMET), d'Energie, Mines et Ressources (EMR) et; du Laboratoire de Recherche du Charbon du Cap-Breton. Cette étude avait pour but de révéler des indications ou preuves que l'extraction minière par longues tailles ait causé une subsidence du fond marin. Les tracés des données géophysiques de trois levés au large de la côte (NSRF - 1978; Dobrocky Seatech Ltée - 1984 et IOB - 1985) et les plans des travaux miniers montrant la position des panneaux de longues tailles furent compilés. Les données géophysiques des trois levés furent ensuite examinées pour des dépressions dans le fond marin de la région de l'extraction minière. Aucune corrélation n'a pu être observée parmi ceux-ci. Ces données ne peuvent donc pas être utilisées dans l'évaluation de la subsidence. Le manque de profils-reperes du fond marin, acquis au prealable de l'extraction minière, se trouve à être le facteur limitant critique dans cette étude.

INDEX

REPORT TEXT

		Page No.
SECTION 1	INTRODUCTION	1
SECTION 2	BATHYMETRY	3
SECTION 3	SURFICIAL GEOLOGY	5
SECTION 4	STRATIGRAPHY	7
SECTION 5	STRUCTURAL GEOLOGY	9
SECTION 6	COMPILATION	11
SECTION 7	ANALYSIS	14
SECTION 8	DATA PRESENTATION	19
	8.1 Map Area 1	20
	8.2 Map Area 2	23
	8.3 Map Area 3	30
	8.4 Map Area 4	39
	8.5 Map Area 5	44
SECTION 9	THEORETICAL MODELLING	51
SECTION 10	CONCLUSIONS	53
SECTION 11	RECOMMENDATIONS	57
	11.1 Seafloor Subsidence	57
	11.2 Bedrock Integrity	61
	REFERENCES	62

INDEX (Continued)

APPENDICES

		Page No.
APPENDIX 1	DATA INVENTORY	63
APPENDIX 2	OPERATIONS SUMMARY	67
APPENDIX 3	SUBSIDENCE MODELLING REPORT	76

FIGURES IN TEXT

FIGURE 1	LOCATION MAP AND REGIONAL BATHYMETRY	2
FIGURE 2	BATHYMETRY OF STUDY AREA	4
FIGURE 3	ISOPACH OF SURFICIAL SEDIMENT	6
FIGURE 4	IDEALIZED STRATIGRAPHIC COLUMN	8
FIGURE 5	DEPTH STRUCTURE ON HARBOUR SEAM AND MAJOR STRUCTURAL FEATURES OFFSHORE	10
FIGURE 6	DISTRIBUTION OF PHALEN COLLIERIES OFFSHORE	12
FIGURE 7	DISTRIBUTION OF HARBOUR AND HUB SEAM COLLIERIES OFFSHORE	13
FIGURE 8	ILLUSTRATION OF CLASSICAL "SUBSIDENCE TROUGH"	16
FIGURE 9	EFFECT OF SEAM DIP ON AXIS OF SUBSIDENCE TROUGH	17
FIGURE 10	EFFECTS OF SUPERIMPOSING SUBSIDENCE PROFILES	18
FIGURE 11	LINE PA-1 DOBROCKY ECHOSOUNDER RECORD	22
FIGURE 12	LINE 107 NSRF SPARKER RECORD	25

FIGURES IN TEXT (Continued)

		Page No.
FIGURE 13	LINE SH-3 DOBROCKY ECHOSOUNDER RECORD	27
FIGURE 14	LINE SH-1 DOBROCKY ECHOSOUNDER RECORD	29
FIGURE 15	BIO ECHOSOUNDER RECORD	32
FIGURE 16	LINE LP-18 DOBROCKY ECHOSOUNDER RECORD	34
FIGURE 17	LINE 115 NSRF SPARKER RECORD	36
FIGURE 18	BIO SIDESCAN SONOGRAM	38
FIGURE 19	LINE 119 NSRF SPARKER RECORD	41
FIGURE 20	LINE 117 NSRF SPARKER RECORD	43
FIGURE 21	LINE E NSRF SPARKER RECORD	46
FIGURE 22	LINE 3.25 NSRF SPARKER RECORD	48
FIGURE 23	LINE 3.0 NSRF SPARKER RECORD	50
FIGURE 24	PLANAR SEAFLOOR AND IRREGULAR SEAFLOOR EFFECT	54

ENCLOSURES

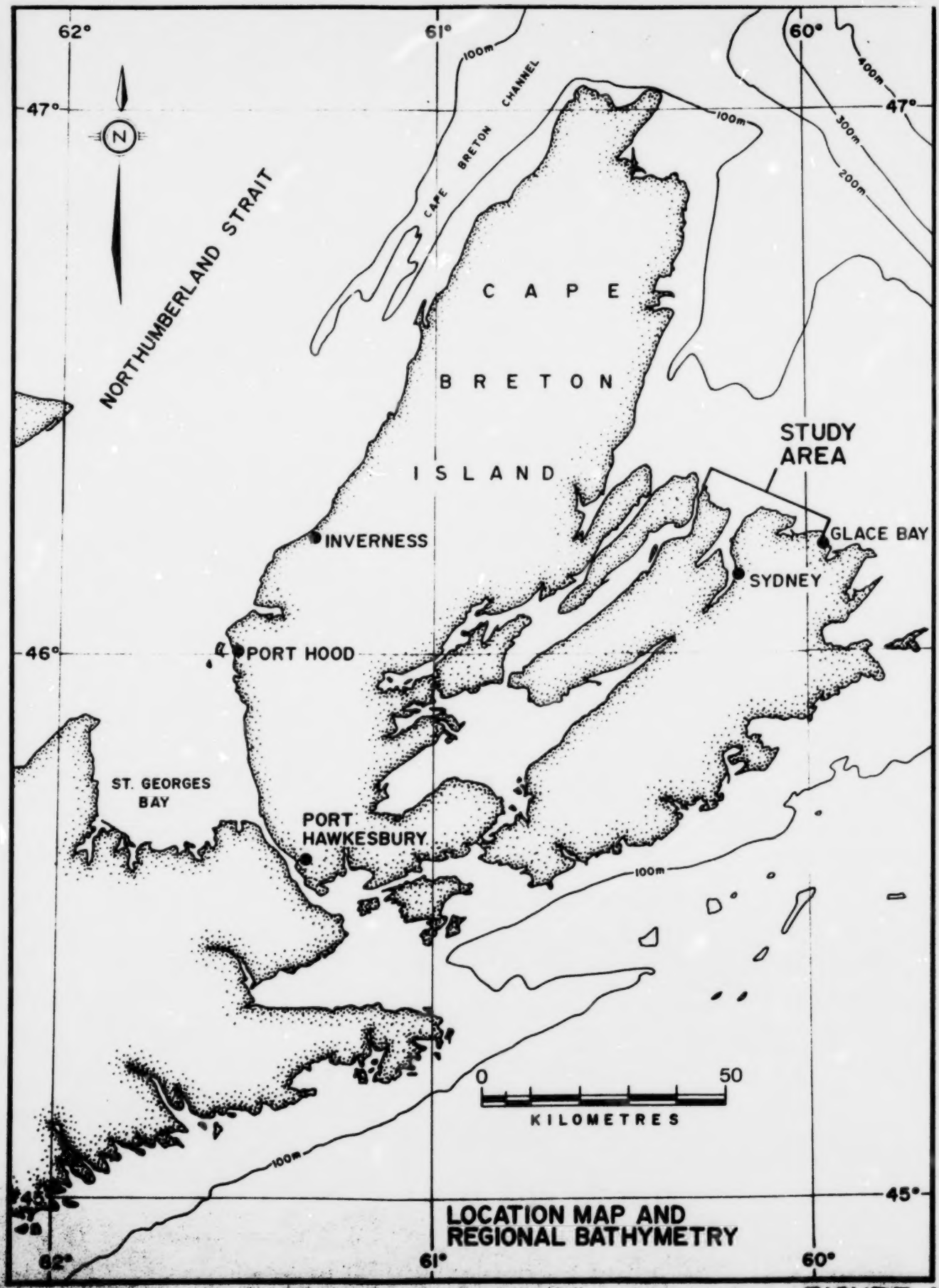
ENCLOSURE 1	MAP 1 - PRINCE COLLIERY - HUB SEAM
ENCLOSURE 2	MAP 2 - PRINCESS AND FLORENCE COLLIERIES - HARBOUR SEAM
ENCLOSURE 3	MAP 3 - HARBOUR 12, 14 AND LINGAN COLLIERIES - HARBOUR SEAM - DOMINION 16 COLLIERY - PHALEN SEAM
ENCLOSURE 4	MAP 4 - NO. 26 COLLIERY - HARBOUR SEAM - NO. 1A AND NO. 1B COLLIERIES - PHALEN SEAM
ENCLOSURE 5	MAP 5 - NO. 4 PHALEN AND NO. 20 HARBOUR COLLIERIES
ENCLOSURE 6	MINEWORKING PLANS, SEAFLOOR PROFILE, SUBSIDENCE CURVE AND CROSS SECTION - LINES 3.0 and 3.25
ENCLOSURE 7	SUBSIDENCE PROFILES - LINES 3.0 and 3.25

SECTION 1

INTRODUCTION

A study of archived marine geophysical data from the Sydney coalfield (Figure 1) was conducted by McGregor GeoScience Ltd. on behalf of the CANMET-EMR-Cape Breton Coal Research Laboratory (CBCRL). The purpose of the study was to search for evidence of seafloor subsidence caused by subsurface coal mining if it could be detected and to measure the subsidence and compare it with theoretical models. This modelling work was conducted in conjunction with Associated Mining Consultants Ltd. The Sydney coalfield is the largest coalfield in eastern Canada having an estimated areal extent of 32,250 sq km. This coalfield consists of a relatively small onshore region and a larger offshore region. The mined areas in the offshore region form a belt extending approximately 7 km offshore. All available geophysical data from within this area has been compiled and evaluated for evidence of mining-induced seafloor subsidence.

This study was conducted as part of a subsidence-monitoring program initiated by CBCRL to assess the applicability of existing subsea mining guidelines. These guidelines determine the amount of seafloor subsidence that may occur before the effects of tensile strain may create the serious risk of mine flooding. According to CANMET (1985) current mining guidelines used in the Sydney coalfield for the avoidance of excessive subsidence have been extrapolated from onshore coalfields in the United Kingdom and the United States. The accuracy of this extrapolation is of concern because it has significant impact on the estimation of coal reserves and mine economics.



LOCATION MAP AND
REGIONAL BATHYMETRY

FIGURE 1

SECTION 2

BATHYMETRY

The seafloor slopes gently northeastward from the shoreline to the 30 m isobath, between 2.5 and 4.0 km offshore (Figure 2). In this depth range the seafloor slope is a gentle 0.4° to 0.7° northeast. Beyond the 30 m isobath the seafloor slope decreases to less than 0.3° northeast.

Superimposed on this regional trend are numerous local bathymetric variations.

SECTION 3

SURFICIAL GEOLOGY

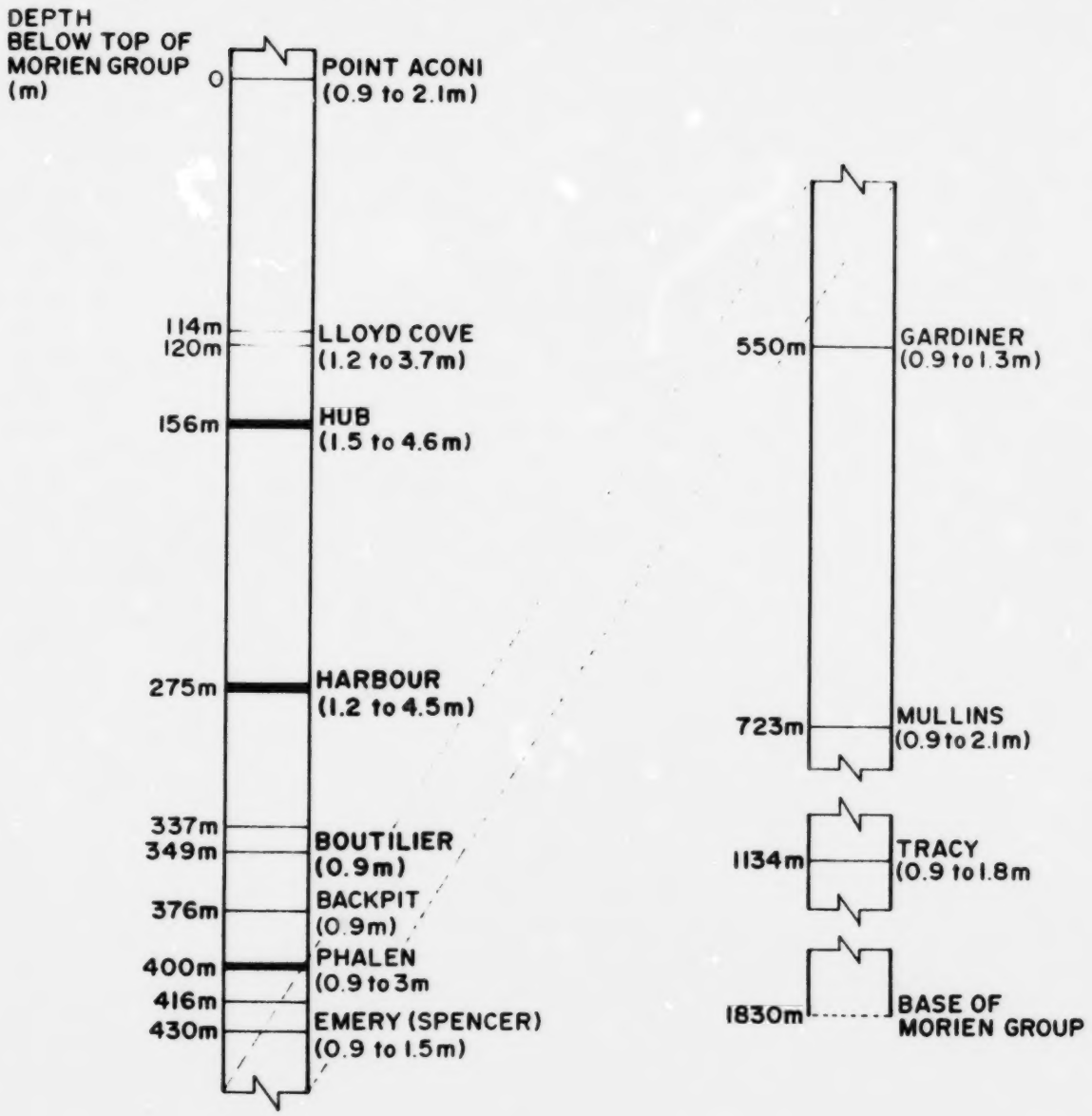
Within the study area the seabed geology is characterized by a broad area of bedrock exposure or thinly-covered bedrock which is interrupted by two major, sediment-filled channels in the bedrock. The surficial sediment thickness offshore is shown in Figure 3. The thickest section of overburden occurs above the northeast trending bedrock channel seaward of Black Point. Sediment thickness in this channel reaches 52 m at the northern margin of the study area. A smaller, less continuous channel occurs to the southeast beyond the mouth of Sydney Harbour.

SECTION 4

STRATIGRAPHY

Three coal seams have been mined in the offshore region. These seams are, from oldest to youngest the Phalen, Harbour and Hub seams. All of these seams occur in the Upper Carboniferous, Morien Group (Pictou Group Equivalent) and on the basis of palynology have been assigned a Westphalian C and D age (Macquebard, 1985). An idealized stratigraphic column (modified from Calder, 1985) is presented as Figure 4.

IDEALIZED STRATIGRAPHIC COLUMN OF THE UPPER CARBONIFEROUS (MORIEN GROUP) SHOWING MAJOR COAL SEAMS



MODIFY FROM CALDER (1985)

FIGURE 4

SECTION 5

STRUCTURAL GEOLOGY

A number of northeast-trending open synclines and anticlines with axes extending from the present day coastline offshore, are the main structural elements effecting the Sydney coalfield strata; Figure 5 (Forgeron, 1979 cited in Boehmer and Giles, 1986). The position of these folds is shown in the Harbour Seam structure map of Figure 5.

Away from these folds the bedrock structure is sympathetic to the regional shoreline trends and has dips ranging from 6° northeast to 12° north.

Two faults have been delineated in the offshore. The position of these faults and the proposed offshore contact between Morien and post-Morien Group strata is also shown in Figure 5 (Forgeron, 1979 cited in Boehmer and Gilles, 1986).

SECTION 6

COMPILATION

Prior to examining the archived geophysical records for anomalous seafloor and subseafloor features related to subsidence, it was necessary to compile the geophysical track plots and mineworking plans. Four offshore geophysical data sets exist for the study area comprised of data collected by: Nova Scotia Research Foundation Corporation (1978); Geoterrex Ltd. (1980); Dobrocky Seatech Ltd. (1984) and the Bedford Institute of Oceanography (1985). An inventory of the data collected is given in Appendix 1. The 1980 Geoterrex data is not included as it was collected prior to mining in the Prince Colliery Area and in the area of the underdeveloped Donkin Colliery. Appendix 2 outlines the geophysical and navigation systems employed in each survey. In addition, the recording parameters are described and data quality assessed for each of these surveys.

The combined geophysical track plots of three surveys and mineworking plans have been compiled in a series of five maps extending from Point Aconi in the west to Glace Bay in the east (Enclosures 1 through 5). Each map displays the geophysical coverage superimposed on the longwall panel plans of one or more collieries. Figures 6 and 7 display an index of map areas and collieries offshore.

To facilitate correlation, the geophysical track plots were reduced to the same scale as the mineworking plans (1:4,800, Transverse Mercator (Imperial Devco Grid)). This process was complicated by large scale differences and varied projections as explained in Appendix 1.

SECTION 7

ANALYSIS

With the geophysical survey track plots superimposed on the mineworking plans (Enclosures 1 though 5) it was possible to examine the geophysical records for anomalous surface and subsurface features which might have resulted from subsidence.

The surface feature considered to characterize subsidence is the classical "subsidence trough". A classical "subsidence trough", as described with reference to a single, rectangular longwall within a flat-lying seam, would appear as a regular "trough" shape. This trough would be centrally and symmetrically positioned with the axis over the longwall's centre (Figure 8). The vertical displacement of surface points would extend beyond the mined area in all directions. The magnitude of the subsidence would depend on the panel's depth, width, length, thickness (extracted height) and the nature of the overlying rock. In addition a horizontal displacement would accompany this vertical displacement.

The theoretical subsidence profile of an isolated and dipping longwall panel is thought to be the same except for migration of the profile's axis downdip (Figure 9).

The subsidence effects of individual longwalls are thought to be cumulative when superimposed with adjacent or overlying profiles (Figure 10a and 10 b). Therefore, in theory, the occurrence of adjacent longwalls should produce a sinusoidal seafloor morphology while overlying longwalls should produce anomalously deep troughs (when compared to the single longwall subsidence profile).

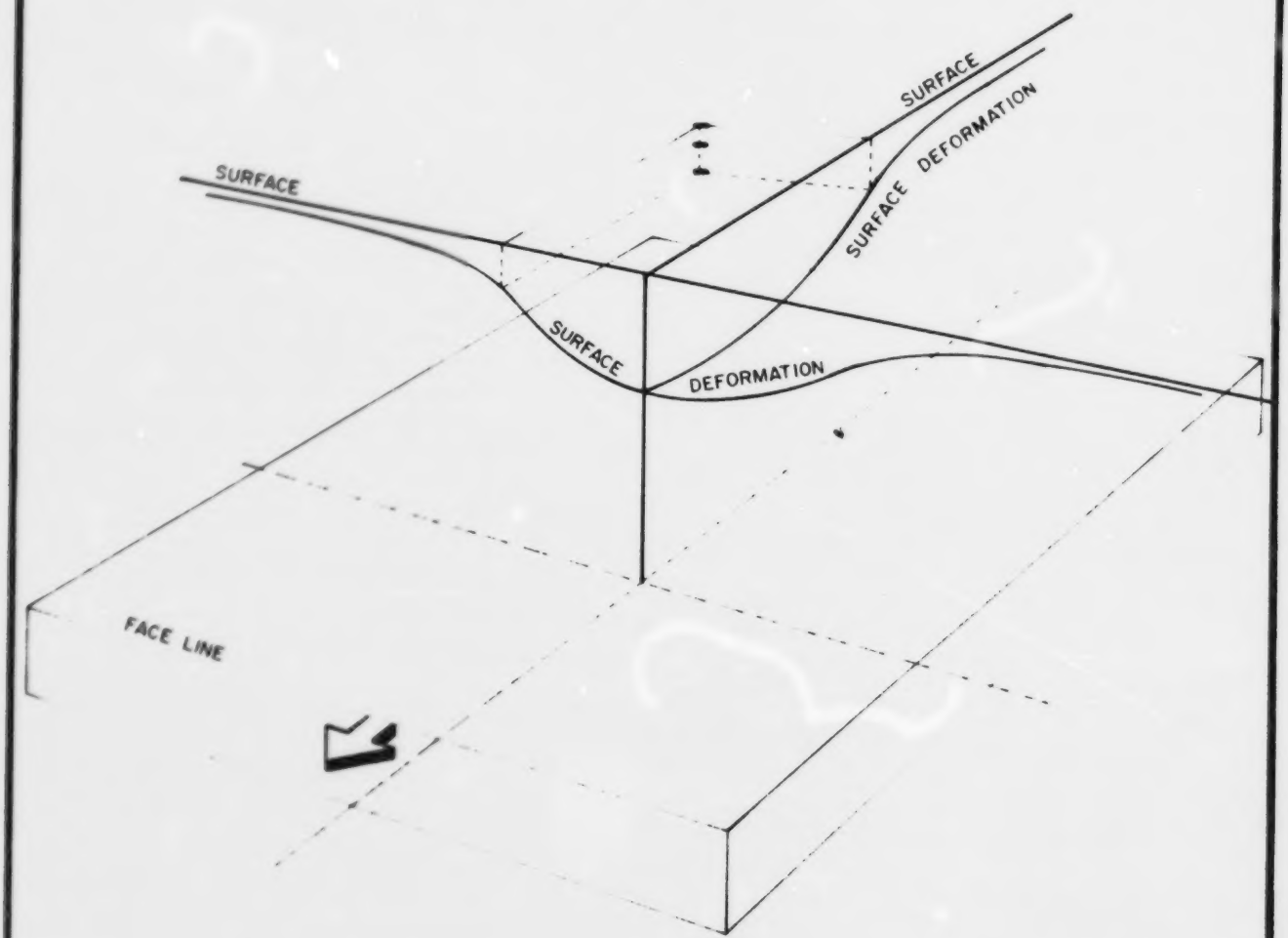
The axial depth of the offshore subsidence troughs in the Sydney Coalfield was originally anticipated to range from 0.3 m to 3.0 m below the level of the surrounding seafloor (CANMET, 1984). Smaller values were expected to typify single longwalls while the larger values were expected to be restricted to areas of overlying longwalls.

In addition to examining the geophysical data for the occurence of classical "subsidence troughs", the data were examined for anomalies in the surficial and subsurface geology.

To examine changes in surficial geology the available sidescan sonar records, the Dobrocky and BIO data sets, were used. These records were examined for evidence of readjustments in seafloor sediment distribution over areas of suspected subsidence.

Several potential subsurface subsidence indicators were considered when examining the seismic data (NSRF, BIO data) including sediment deformation and dislocation of the bedrock. The occurrence of methane gas migration and concentration resulting from bedrock faulting or extension and compression were also thought to be possible indicators of subsidence.

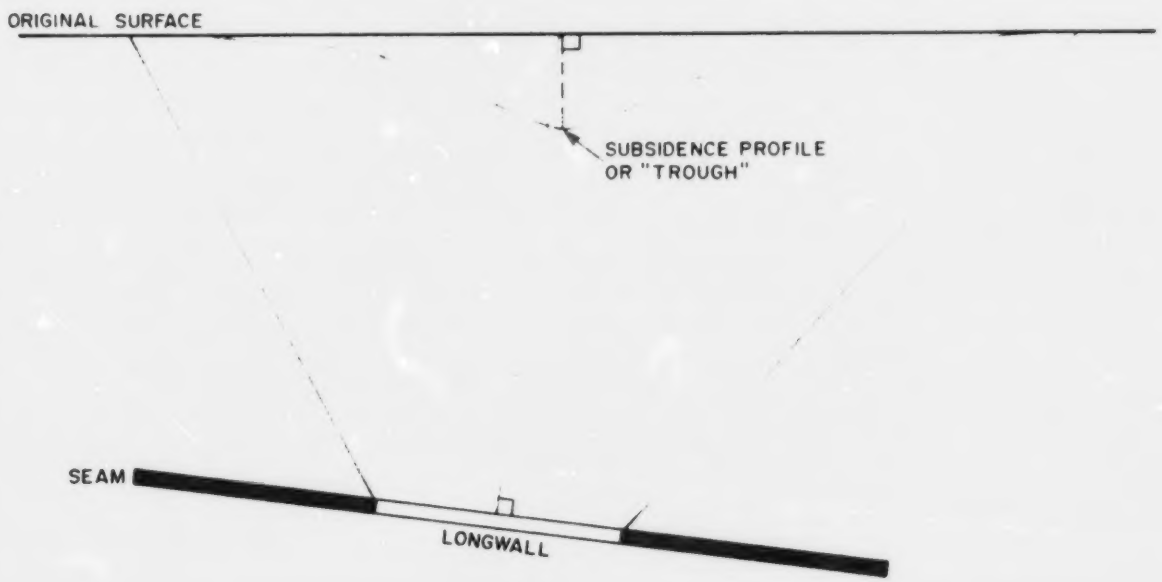
ILLUSTRATION OF CLASSICAL "SUBSIDENCE TROUGH"



AFTER AMCL (1984)

FIGURE 8

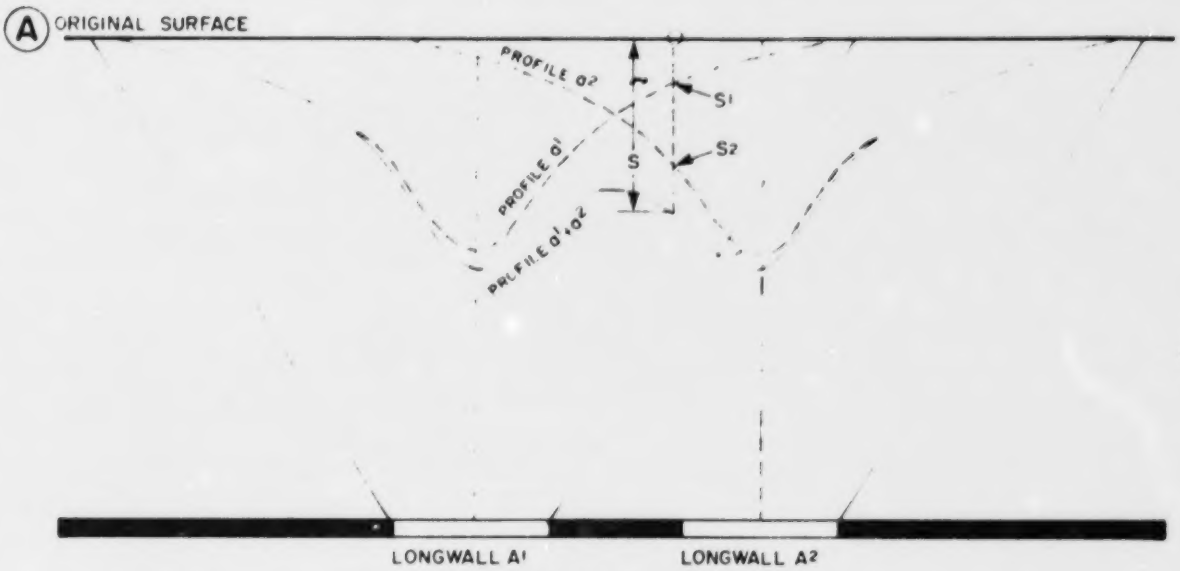
EFFECT OF SEAM DIP ON AXIS OF SUBSIDENCE TROUGH



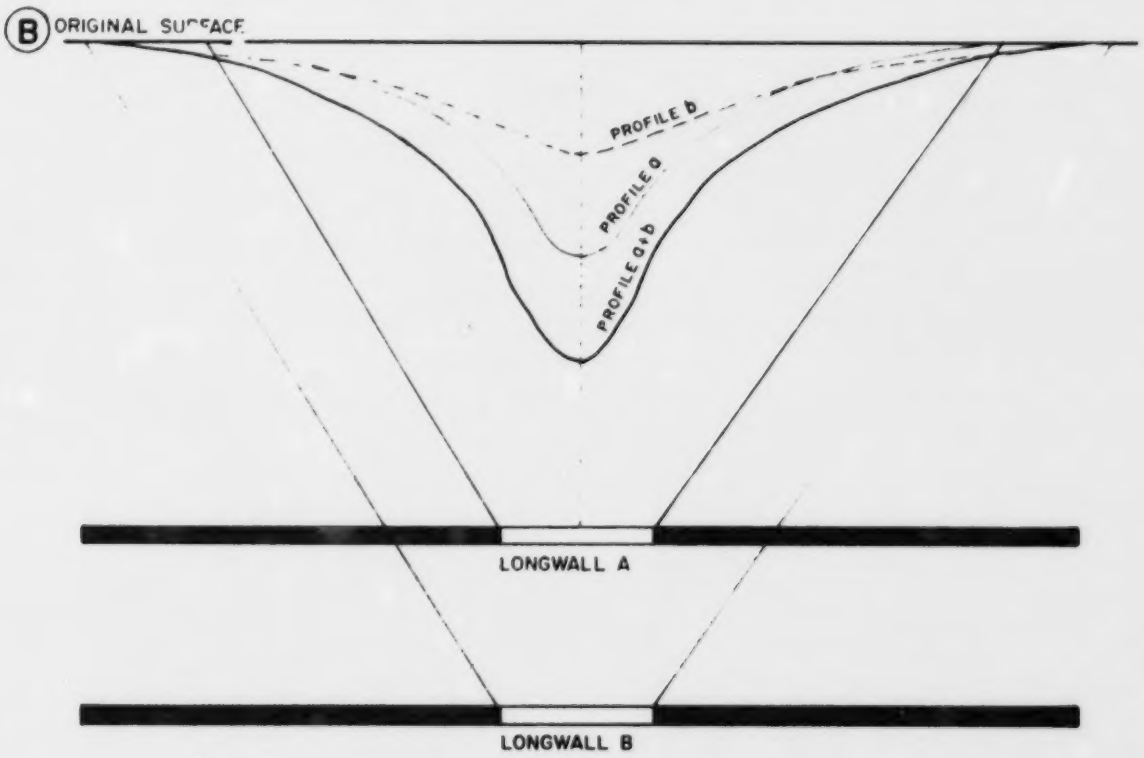
AFTER AMCL (1984)

FIGURE 9

EFFECTS OF SUPERIMPOSING SUBSIDENCE PROFILES



ADJACENT LONGWALLS



OVERLYING LONGWALLS

AFTER AMCL (1984)

FIGURE 10a,b

SECTION 8

DATA PRESENTATION

The following section presents a series of geophysical records (echosounder, sidescan, seismic) collected in Map Areas 1 through 5 (Enclosures 1 through 5). These represent the best records from the three data sets (NSKF, Dobrocky, BIO) with respect to data quality and proximity and orientation of the lines relative to the longwall mines.

Captions identifying the possible subsidence indicators and explaining data type, scales, recording parameters and system noise, accompany each figure. Schematic representations of the relevent colliery longwalls are shown beneath each record. Neither vertical scale, panel dimension nor panel dip are inferred in these longwall schematics.

8.1 Map Area 1

The following section presents one example of echosounder data from the Dobrocky survey and shows the horizontal position of underlying longwall panels. This area extends offshore from Point Aconi for approximately 5 km and contains one site of longwall mining - the Prince Colliery (Hub Seam).

Description: Figure 11

Figure 11 is an echosounder record from Line PA-1 (the Dobrocky survey). This record was collected with echosounder vertical range 16.5 m and chart speed 5.0 cm/min. The seafloor profile has a vertical exaggeration of 30:1 (a function of vessel speed and recorder settings) and an average echosounder heave of less than 0.5 m. The irregularity of the seafloor probably results from outcropping of northward-dipping bedrock. Beneath this profile is a schematic representation of the Prince Colliery longwalls (Hub Seam) illustrating their horizontal position. The position of these longwalls is taken from the compiled track plot and mineworking maps (Enclosure 1).

Three longwall panels, No. 1E, No. 2E and No. 3E, had been mined in the subsurface prior to the acquisition of this data. The corresponding seafloor profile appears to lack any correlation with the longwall positions. For example, Panel Nos. 1E and 3E correspond to bathymetric highs while the pillar zone between Nos. 2E and 3E corresponds to a major seafloor depression.

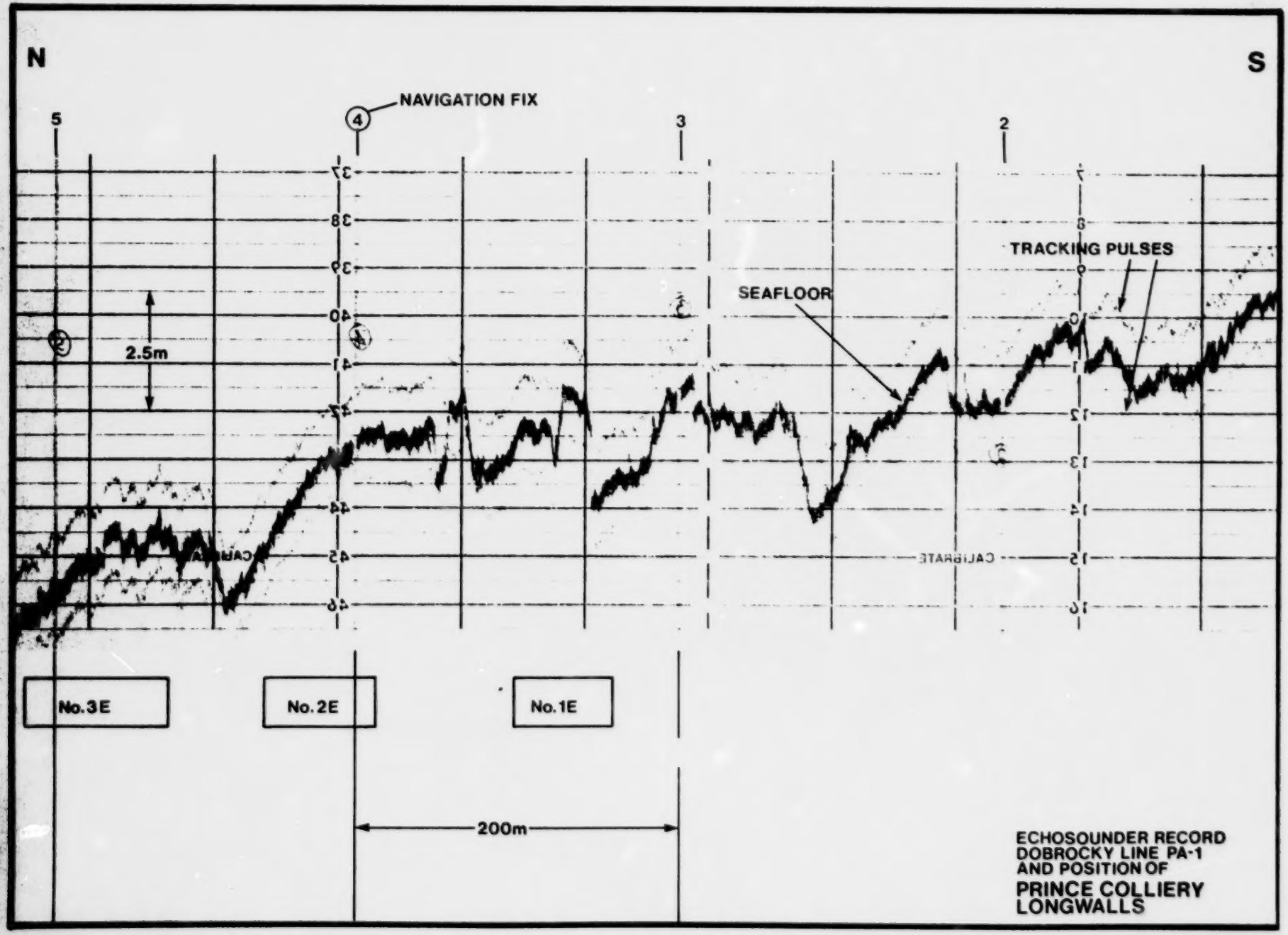

N
S
NAVIGATION FIX
4
5
3
2
TRACKING PULSES
SEAFLOOR
2.5m
No.3E
No.2E
No.1E
200m
ECHOSOUNDER RECORD
DOBROCKY LINE PA-1
AND POSITION OF
PRINCE COLLIERY
LONGWALLS

FIGURE 11

8.2 Map Area 2

The following section presents three examples of seafloor profile data and their corresponding longwall panels. These include one NSRF sparker profile and two Dobrocky echosounder profiles. These data were collected from Map Area 2, which extends offshore from Sydney Harbour for approximately 5 km. Two inactive collieries, the Florence and the Princess, both previously longwall-mining the Harbour Seam, occur in this area (Enclosure 2).

Description: Figure 12

Figure 12 shows the portion of a NSRF sparker record from Line 107 (Figure 12). This record was collected at a sweep speed of 500 msec. The seafloor profile has a vertical exaggeration of 10:1. A bubble pulse (1) approximately 4 msec (5 m) in length masks the shallow subsurface geology. A gentle northward slope and a ridge-bounded trough characterize the seafloor. The irregular ridges on the seafloor probably result from outcropping of more resistant northward dipping strata.

Beneath this record is a schematic representation of the Florence Colliery longwalls (Harbour Seam).

The anomalous seafloor trough occurring on the seismic record between Fixes 8 and 10 does not appear to coincide with the position of the Florence longwalls. For example the trough is deepest at Fix 9.25 which is a pillar area. In addition, the 11N, 12N and 17N longwall panels occur below bedrock ridges rather than occurring below bedrock troughs.

(1) A bubble pulse is a type of seismic noise generated by resonance of a cavity in the water created by discharge of the sparker source. The width of the bubble pulse is calculated here using an assumed bedrock velocity of 2500 m/s.

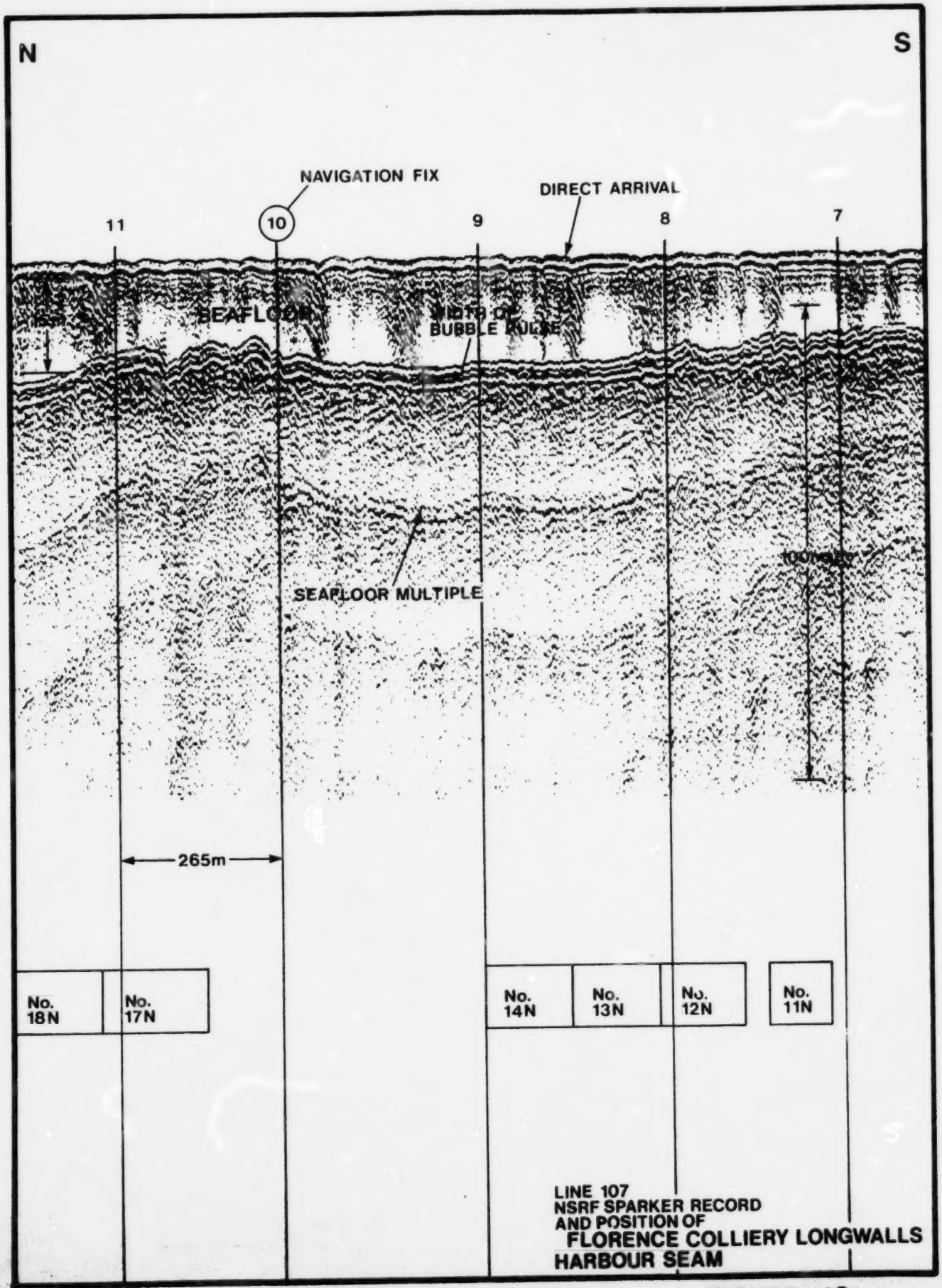

N
S
NAVIGATION FIX
DIRECT ARRIVAL
11
10
9
8
7
SEAFLOOR
WIDTH OF BUBBLE PULSE
SEAFLOOR MULTIPLE
265m
No. 18N
No. 17N
No. 14N
No. 13N
No. 12N
No. 11N
LINE 107
NSRF SPARKER RECORD
AND POSITION OF
FLORENCE COLLIERY LONGWALLS
HARBOUR SEAM

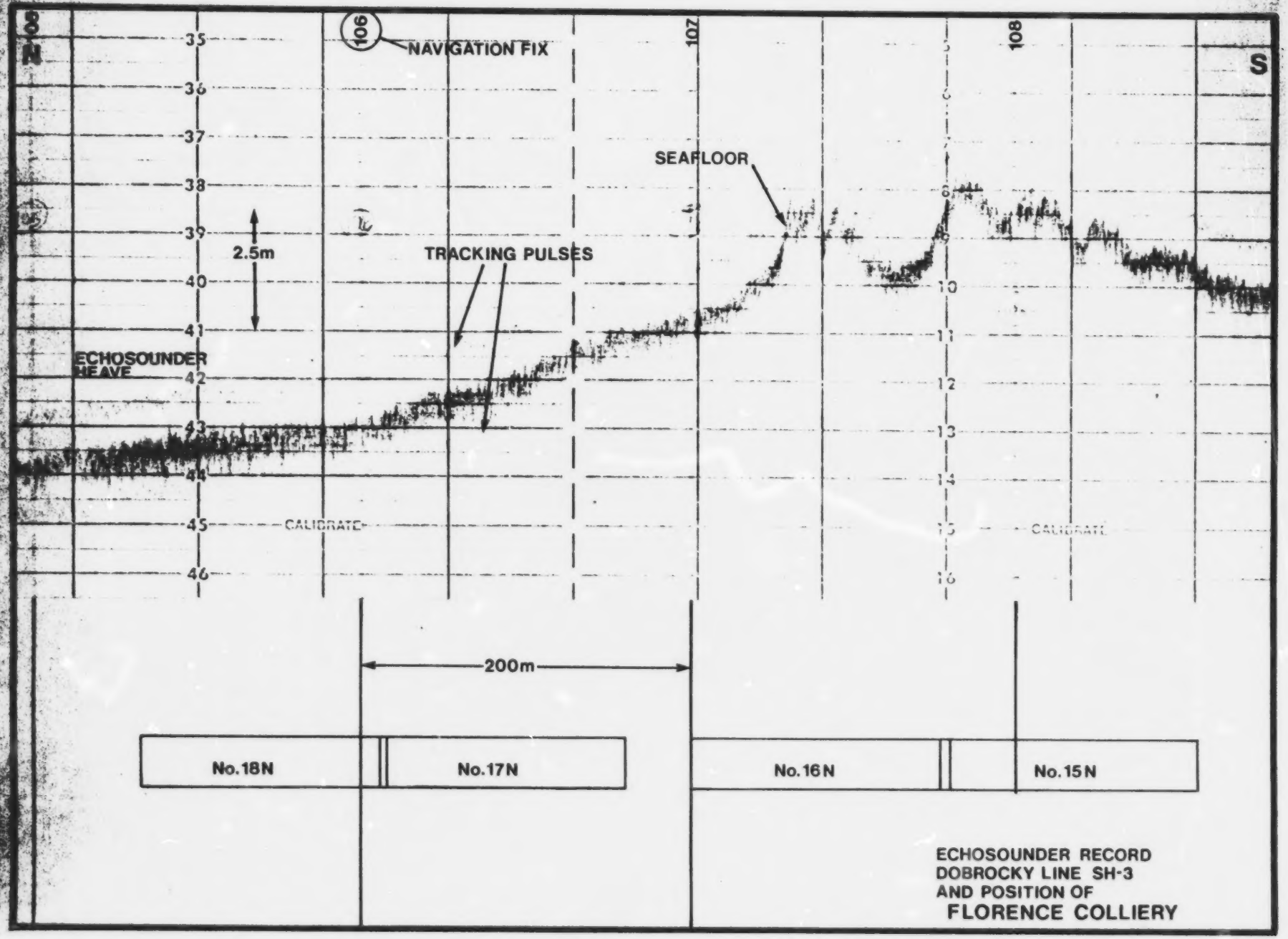
FIGURE 12

Description: Figure 13

Figure 12 shows a Dobrocky echosounder record from Line Sh-3 (Figure 13). This record was collected at a vertical scale of 16.5 m (top to bottom) and a chart speed of 5.0 cm/min. The seafloor profile has a vertical exaggeration (determined by vessel speed) of 1:27.6 and an average echosounder heave of less than 0.5 m. The north slope of the seafloor profile displays a bedrock ridge between Fixes 107.5 and 108.5.

Beneath this record is a schematic representation of the Florence Colliery longwalls (Harbour Seam).

The anomalous bedrock ridge between Fix 107.5 and 108.5 appears to coincide with the No. 16N and No. 15N longwalls. This is contrary to the theoretical predictions. It is therefore concluded than an evaluation of subsidence effects cannot be made on this line.



ECHOSOUNDER RECORD
DOBROCKY LINE SH-3
AND POSITION OF
FLORENCE COLLIERY

FIGURE 13

Description: Figure 14

A Dobrocky echosounder record from Line SH-1 is displayed on Figure 14. This record was collected at a vertical scale of 16.5 m full sweep and a chart speed of 5.0 cm/min. The seafloor profile has a vertical exaggeration of 32:1 and an average echosounder heave of less than 0.5 m. A smooth plane dipping northward characterizes the seafloor.

Beneath this record is a schematic representation of the Florence Colliery longwalls (Harbour Seam).

Because the seafloor slope remains constant over the No. 25S and No. 26S longwalls, it is concluded that no correlation exists between longwall positions and seafloor morphology on this line. However, according to seismic data (NSRF Lines 107 and JJ) the seabed is comprised of 3-5 m of sediment at this location. The mobility of this zone could explain the absence of a longwall associated depression on the seafloor. A more stable surface on which any subsidence effects would be visible is the top of bedrock. Examination of the NSRF seismic data over an associated trough failed to reveal any subseafloor depression coincident with a longwall mine thus reaffirming the lack of any correlation between bedrock structure and longwall positions.

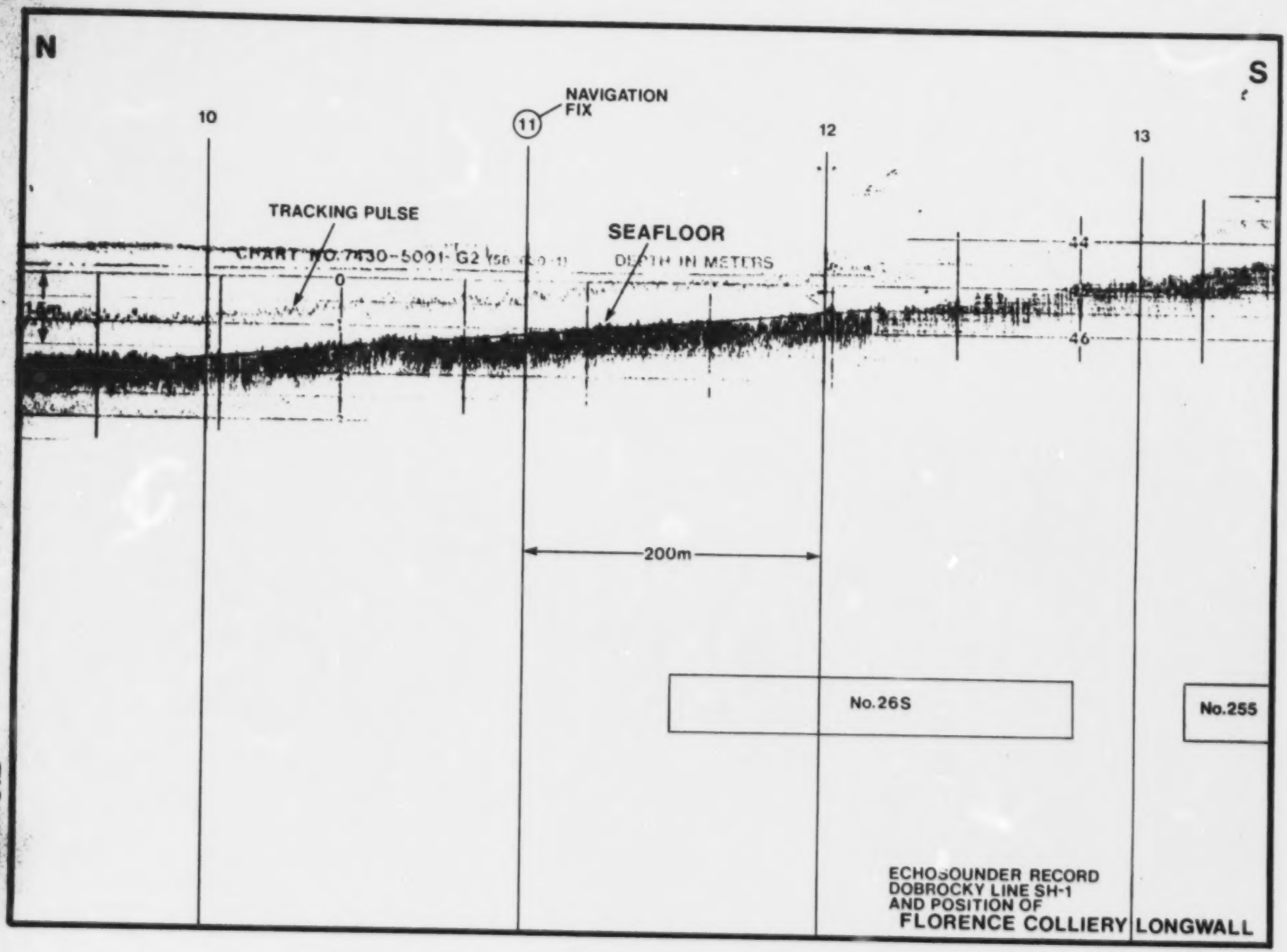

N
S
10
NAVIGATION FIX
11
12
13
TRACKING PULSE
SEAFLOOR
DEPTH IN METERS
0
44
46
15m
200m
No.26S
No.255
ECHOSOUNDER RECORD
DOBROCKY LINE SH-1
AND POSITION OF
FLORENCE COLLIERY LONGWALL

FIGURE 14

8.3 Map Area 3

The following section compares three examples of profiles and their corresponding longwall panels in Map Area 3 (Enclosure 3). These data include a NSRF sparker profile, a Dobrocky and a B10 echosounder profile. Map Area 3 extends from the New Waterford-Lingan shoreline, northward for approximately 3 km and contains two sites of longwall mining. These are a) No. 16 Colliery (Phalen Seam) and No. 12, 14 and Lingan Collieries (Harbour Seam).

Description: Figure 15

Figure 15 shows a BIO echosounder record collected during Cruise 85-037. This record was collected at a sweep speed of 250 msec. The seafloor profile has a vertical exaggeration of 1:39, an average echosounder heave of 1 m and poor continuity of seafloor reflection because of vessel motion. This discontinuity appears as "white outs" on the record and is likely due to aeration of the echosounder transducer (1) in rough weather. The seafloor is characterized by a slightly irregular northeastward dipping plane with a local increase in slope between Fixes 3061706 and 3061708.

Beneath this record is a schematic representation of the Lingan Colliery longwalls (Lingan Seams). Neither panel depth or dip are inferred in the schematic.

No correlation can be established between longwall positions and seafloor morphology on this line. As an example the seabed trace above the No. 5E panel is a ridge while above the No. 4E panel it is a trough. The echosounder profile suffers from too much vertical exaggeration, a sweep speed which is too slow and high amplitude heave motion.

(1) Aeration is the decoupling of an echosounder's transducer from the water by air bubbles - the result of excessive ship heave.

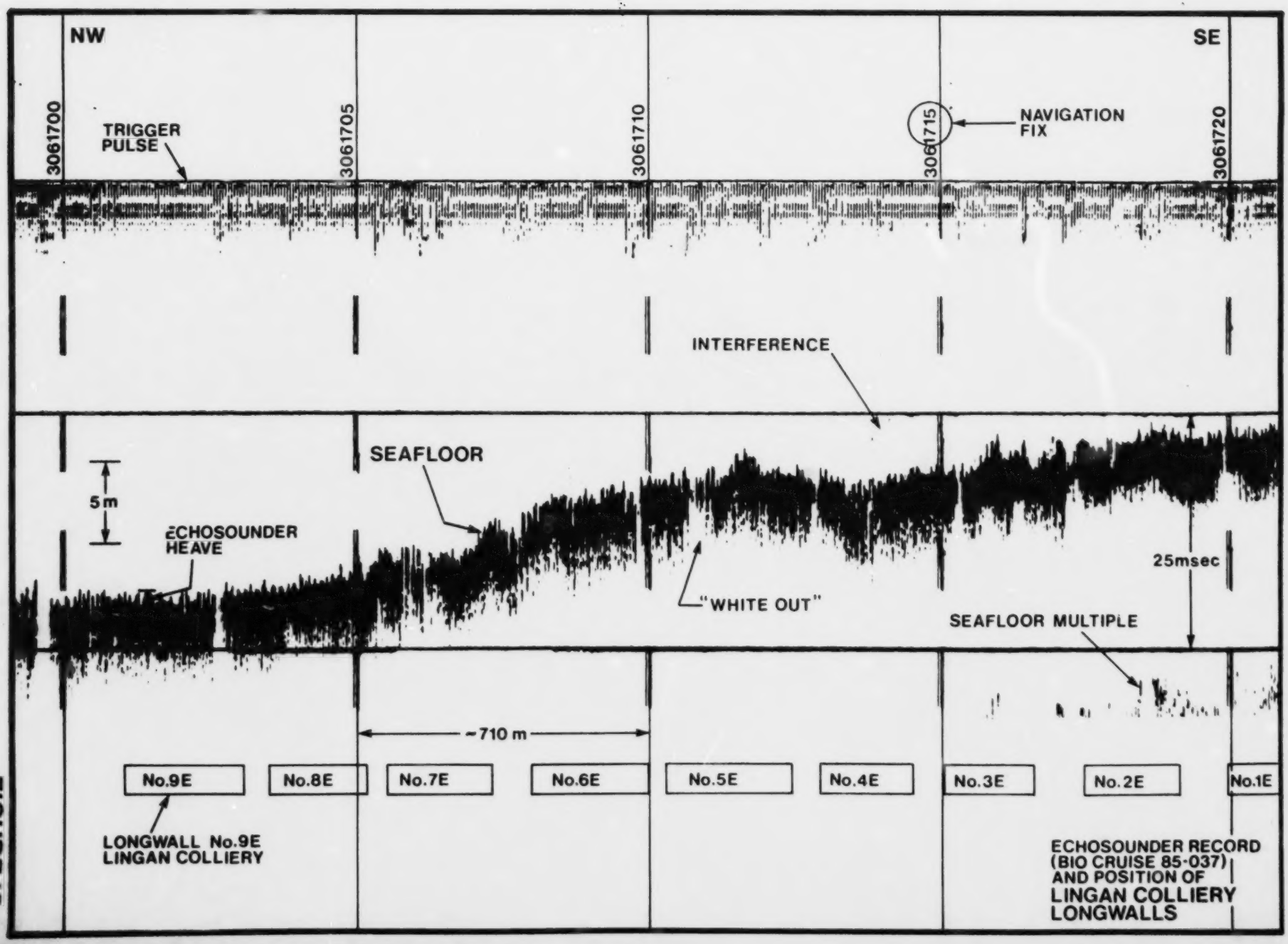

NW
SE
3061700
3061705
3061710
3061715
3061720
TRIGGER PULSE
NAVIGATION FIX
INTERFERENCE
SEAFLOOR
5m
ECHOSOUNDER HEAVE
"WHITE OUT"
25msec
SEAFLOOR MULTIPLE
~710 m
No.9E
No.8E
No.7E
No.6E
No.5E
No.4E
No.3E
No.2E
No.1E
LONGWALL No.9E LINGAN COLLIERY
ECHOSOUNDER RECORD (BIO CRUISE 85-037) AND POSITION OF LINGAN COLLIERY LONGWALLS

FIGURE 15

Description, Figure 16

Figure 16 shows a Dobrocky echosounder record from line LP-18. This record was collected at a range of 16.5 m and a chart speed of 3.5 cm/min. The seafloor profile has a vertical exaggeration of 1:60 and an average echosounder heave of less than 0.75 m. The irregularity of the seafloor may result from outcropping of northeastward-dipping bedrock.

Beneath this record is a schematic representation of the Lingan Colliery longwalls (Harbour Seam).

Two panels, No. 3W and No. 6E, occur in the mining horizon. The corresponding seafloor trace does not appear to reflect longwall positions. In fact, the largest seafloor trough, occurring at Fix 212.5, is above a pillar zone.

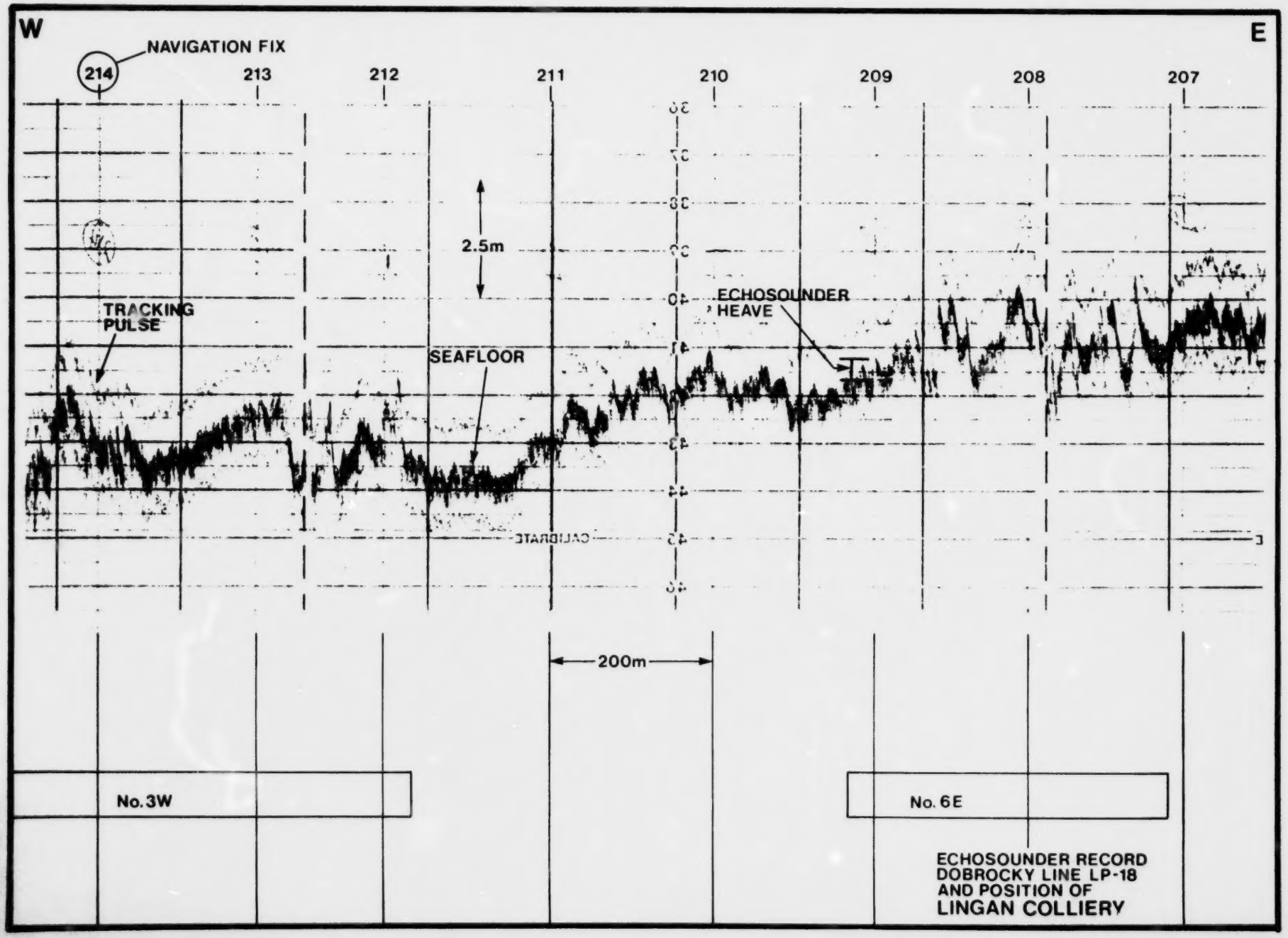

W
E
NAVIGATION FIX
214
213
212
211
210
209
208
207
2.5m
TRACKING PULSE
SEAFLOOR
ECHOSOUNDER HEAVE
200m
No. 3W
No. 6E
ECHOSOUNDER RECORD
DOBROCKY LINE LP-18
AND POSITION OF
LINGAN COLLIERY

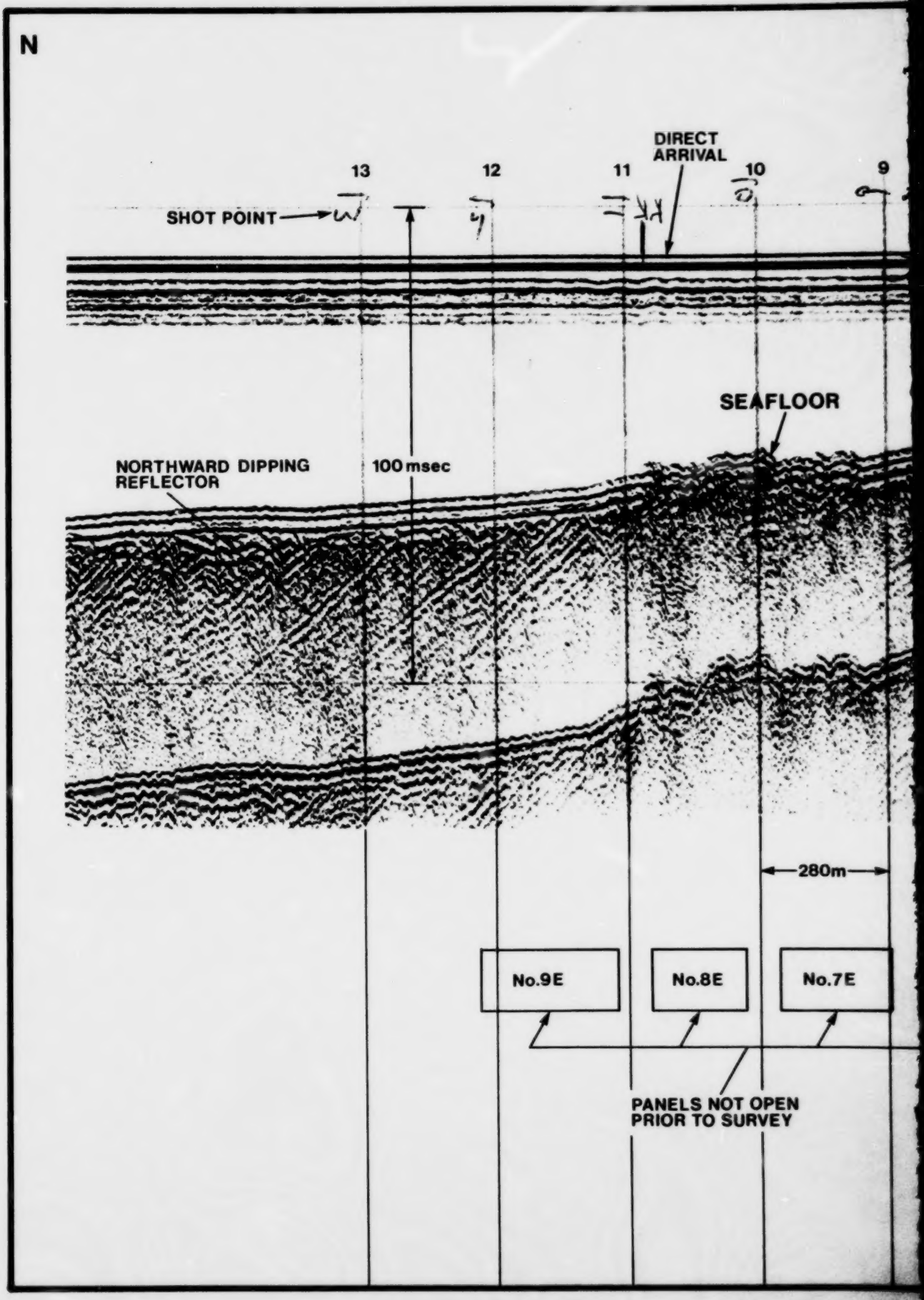
FIGURE 16

Description: Figure 17

The NSRF sparker profile from Line 115 is presented on Figure 17. This record was collected at a sweep speed of 500 msec. The seafloor profile has a vertical exaggeration of 12:1. A bubble pulse approximately 4 msec (5 m) in length masks the shallow subsurface geology. Bedrock is interpreted as outcropping on the seafloor from shot point 11 southward.

Beneath this record is a schematic representation of the Lingan Colliery longwalls (Harbour Seam). Neither vertical scale, panel dimension or panel dip are inferred in the schematic.

There is no apparent correlation of seafloor subsidence and the position of the Lingan longwalls. The effects of subsidence (if any) can not be evaluated with this data.


N
DIRECT ARRIVAL
13
12
11
10
9
SHOT POINT
SEAFLOOR
NORTHWARD DIPPING REFLECTOR
100 msec
280m
No.9E
No.8E
No.7E
PANELS NOT OPEN PRIOR TO SURVEY

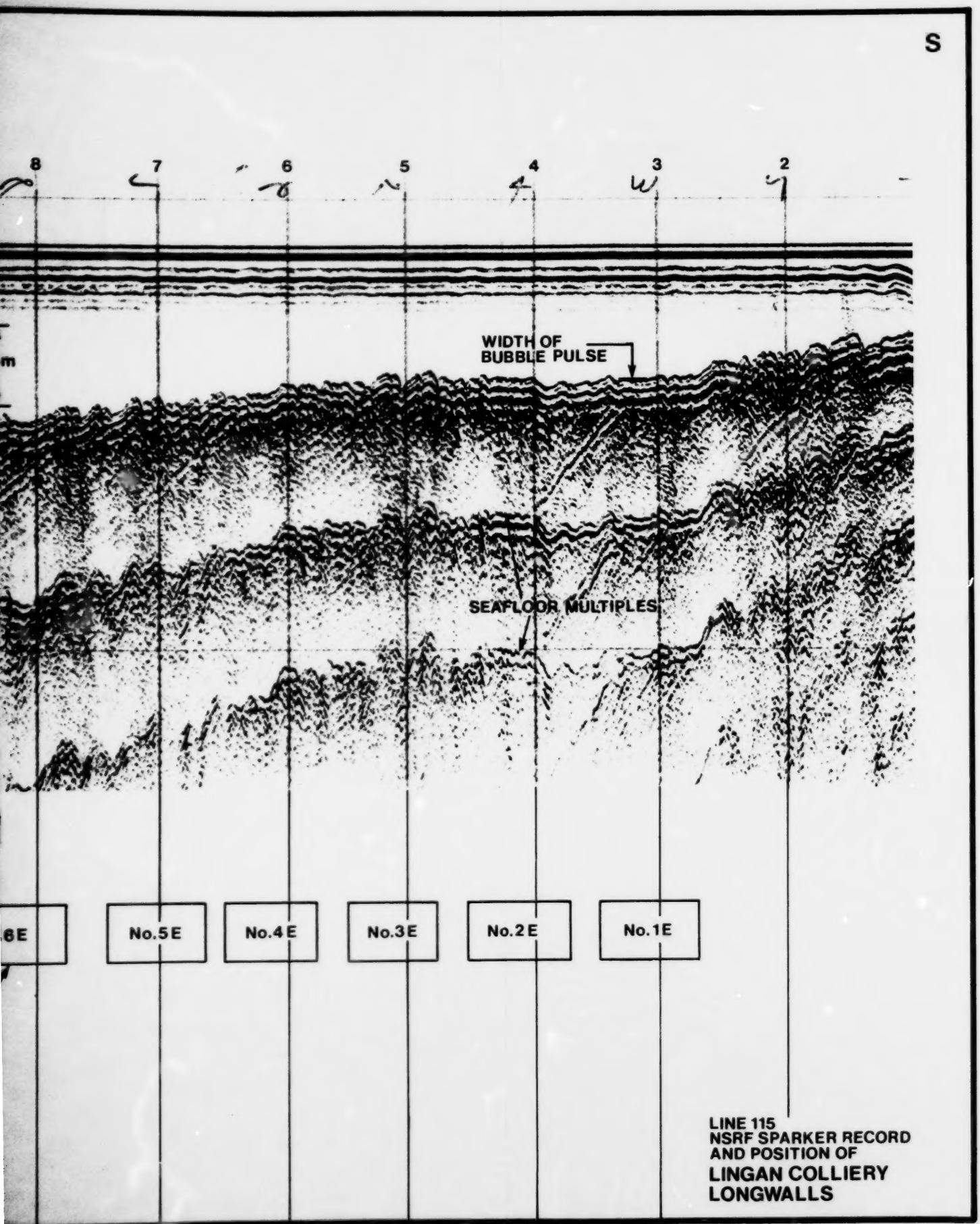

S
8
7
6
5
4
3
2
WIDTH OF
BUBBLE PULSE
SEAFLOOR MULTIPLES
6E
No.5E
No.4E
No.3E
No.2E
No.1E
LINE 115
NSRF SPARKER RECORD
AND POSITION OF
LINGAN COLLIERY
LONGWALLS

FIGURE 17

Description: Figure 18

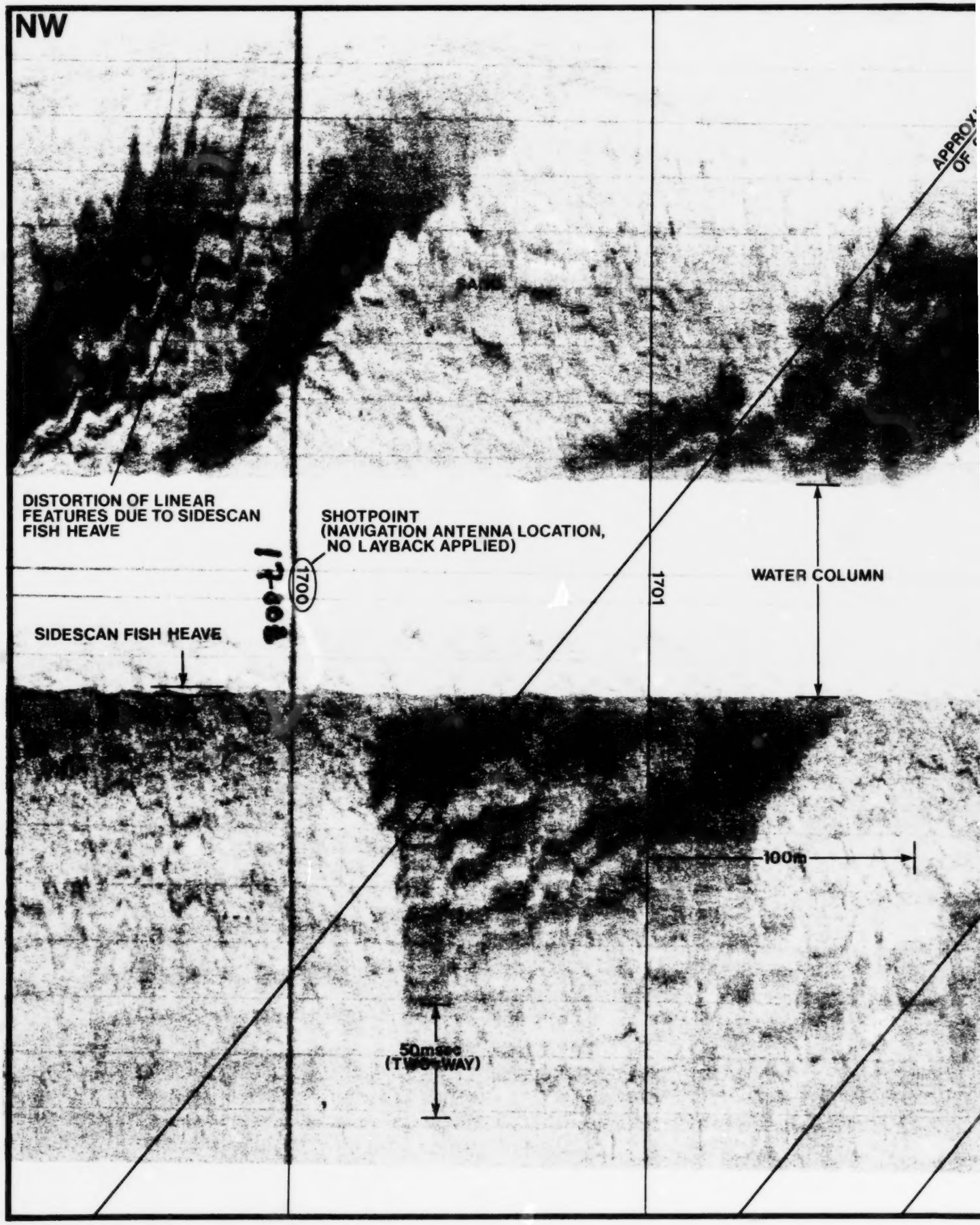
Figure 18 shows a BIO sidescan sonar record collected over the Lingan Colliery. This record was collected at a sweep speed of 0.25 seconds/channel and with an on-line compression ratio of 1:0.85. Sidescan fish heave, measured from the seafloor profile to average 2 m, has distorted linear features on the record.

The surficial geology at this location has been divided into two zones (Figure 18). In zone 1 alternating bands of low and high acoustic reflectivity characterize the seafloor. These bands are interpreted from the sidescan, seismic, echosounder and grab sample data to correspond to sand and sand and gravel respectively. Zone 2 is characterized by high reflectivity and the presence of ridges and acoustic shadows. This zone is interpreted as carboniferous bedrock. The acoustic shadows result from rock surface irregularities, bedding and jointing surfaces.

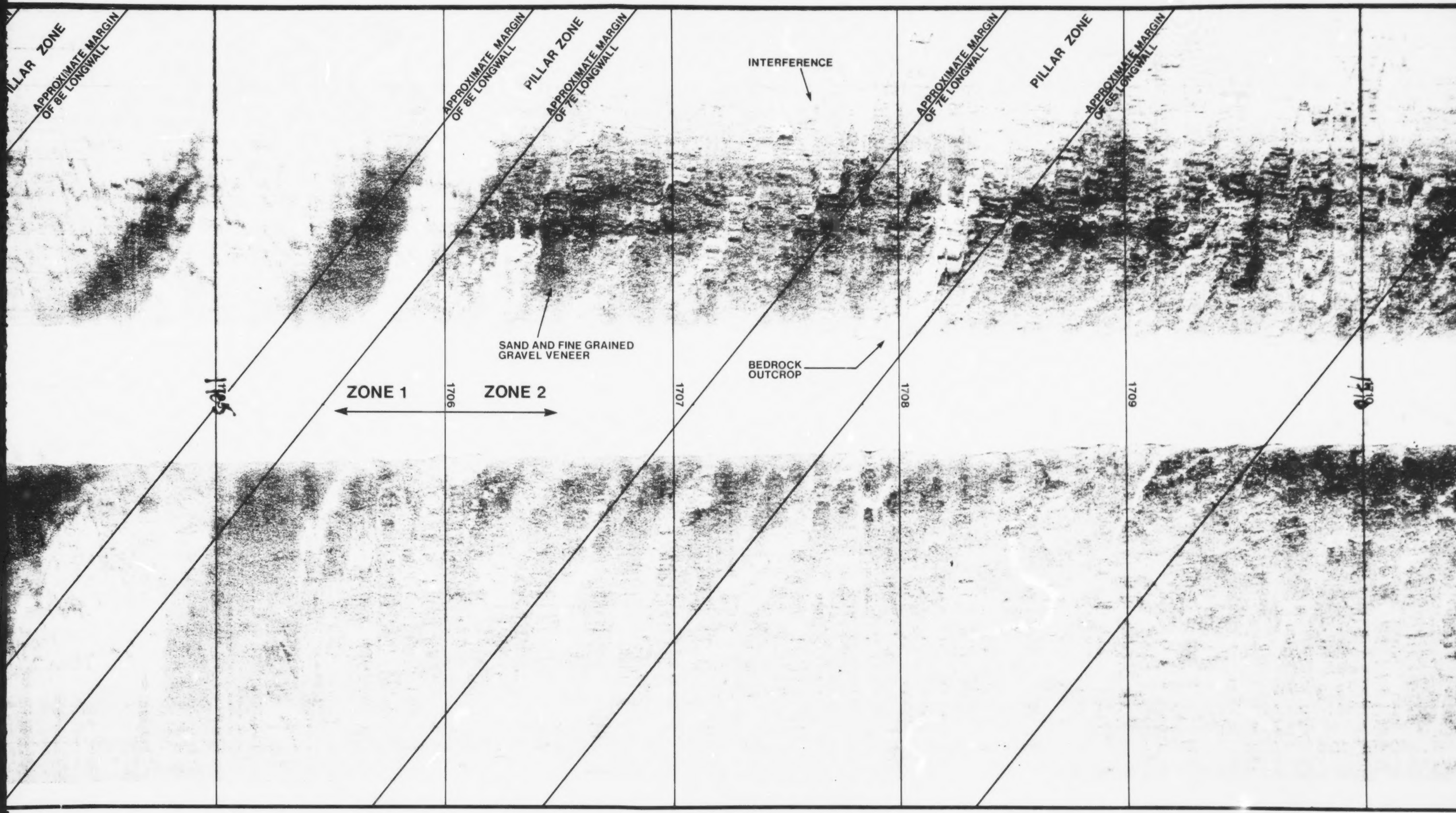
Projected onto this planview record is a schematic representation of the Lingan Colliery mine workings. The positions of these longwalls have been taken from the compiled track plot and mineworking maps (Enclosure 3). The effects of angular distortions and laybacks on the sidescan records have been corrected so that the longwall positions are referenced correctly to the sidescan record.

It was originally postulated that subsidence effects might be manifested at the seafloor as small troughs above longwall panels and small ridges above the mine pillars. In addition it was reasoned that subsidence effects might be manifested at the seabed by the lateral change in the surficial geology.

Upon examination of the sidescan data, such as the one presented here, it has been observed that this is not the case. For example the surficial geology above longwalls 9E and 8E does not differ from that above the intermediate pillar. Neither changes in sediment type or seafloor slope occcur. Similar observations have been made regarding the 7E and 6E longwall and their pillar.


NW
DISTORTION OF LINEAR FEATURES DUE TO SIDESCAN FISH HEAVE
SHOTPOINT (NAVIGATION ANTENNA LOCATION, NO LAYBACK APPLIED)
1700
1701
SIDESCAN FISH HEAVE
WATER COLUMN
100m
50msec (TWO-WAY)

INTERFERENCE
APPROXIMATE MARGIN OF 9E LONGWALL
PILLAR ZONE
APPROXIMATE MARGIN OF 8E LONGWALL
1702
1703
1704
1705


ILLAR ZONE
APPROXIMATE MARGIN OF 8E LONGWALL
APPROXIMATE MARGIN OF 8E LONGWALL
PILLAR ZONE
APPROXIMATE MARGIN OF 7E LONGWALL
INTERFERENCE
APPROXIMATE MARGIN OF 7E LONGWALL
PILLAR ZONE
APPROXIMATE MARGIN OF 6S LONGWALL
SAND AND FINE GRAINED GRAVEL VENEER
BEDROCK OUTCROP
ZONE 1
ZONE 2
1705
1706
1707
1708
1709
1710

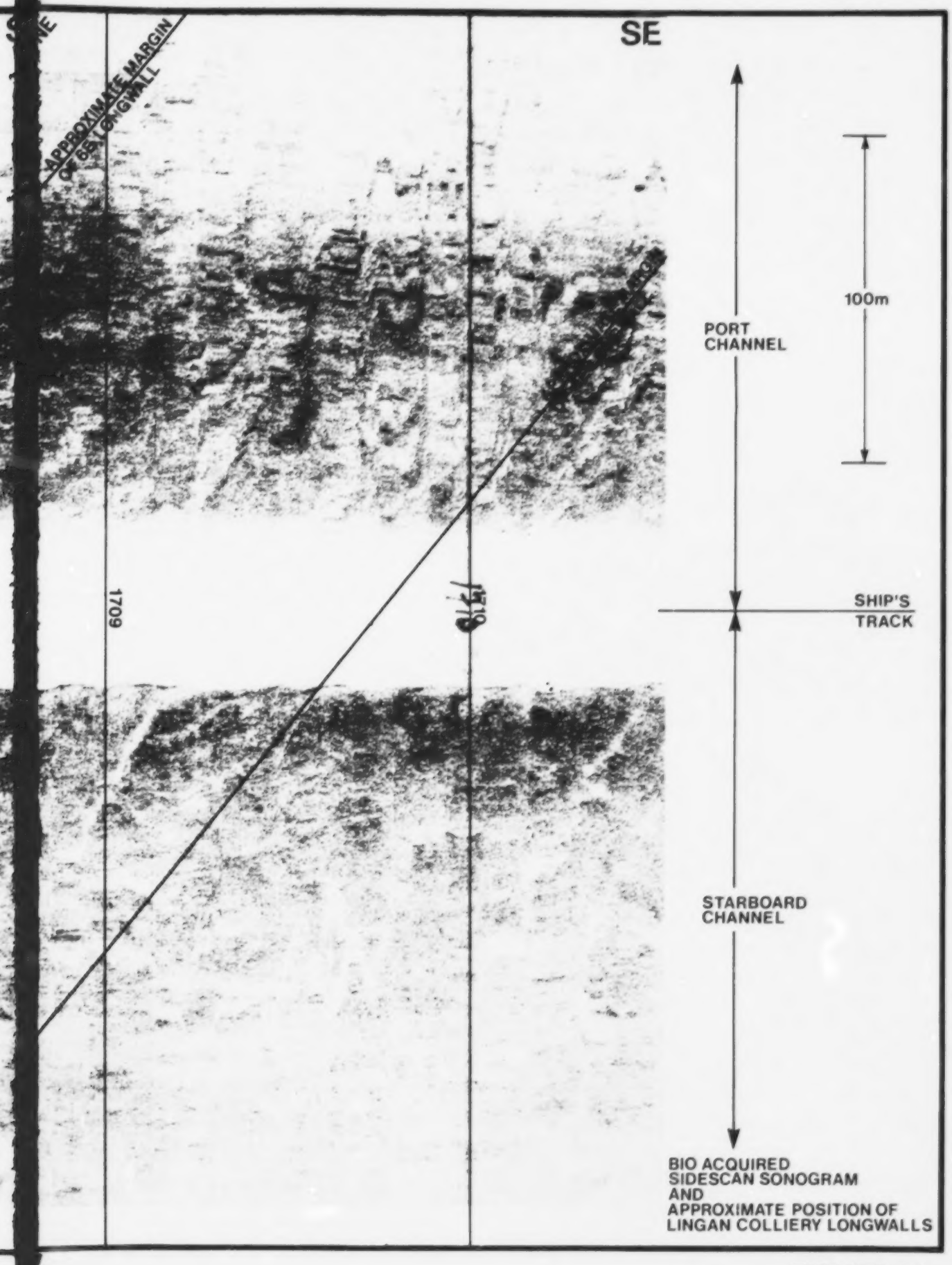

SE
APPROXIMATE MARGIN OF 65 LONGWALL
1709
1719
100m
PORT CHANNEL
SHIP'S TRACK
STARBOARD CHANNEL
BIO ACQUIRED SIDESCAN SONOGRAM AND APPROXIMATE POSITION OF LINGAN COLLIERY LONGWALLS

FIGURE 18

8.4 Map Area 4

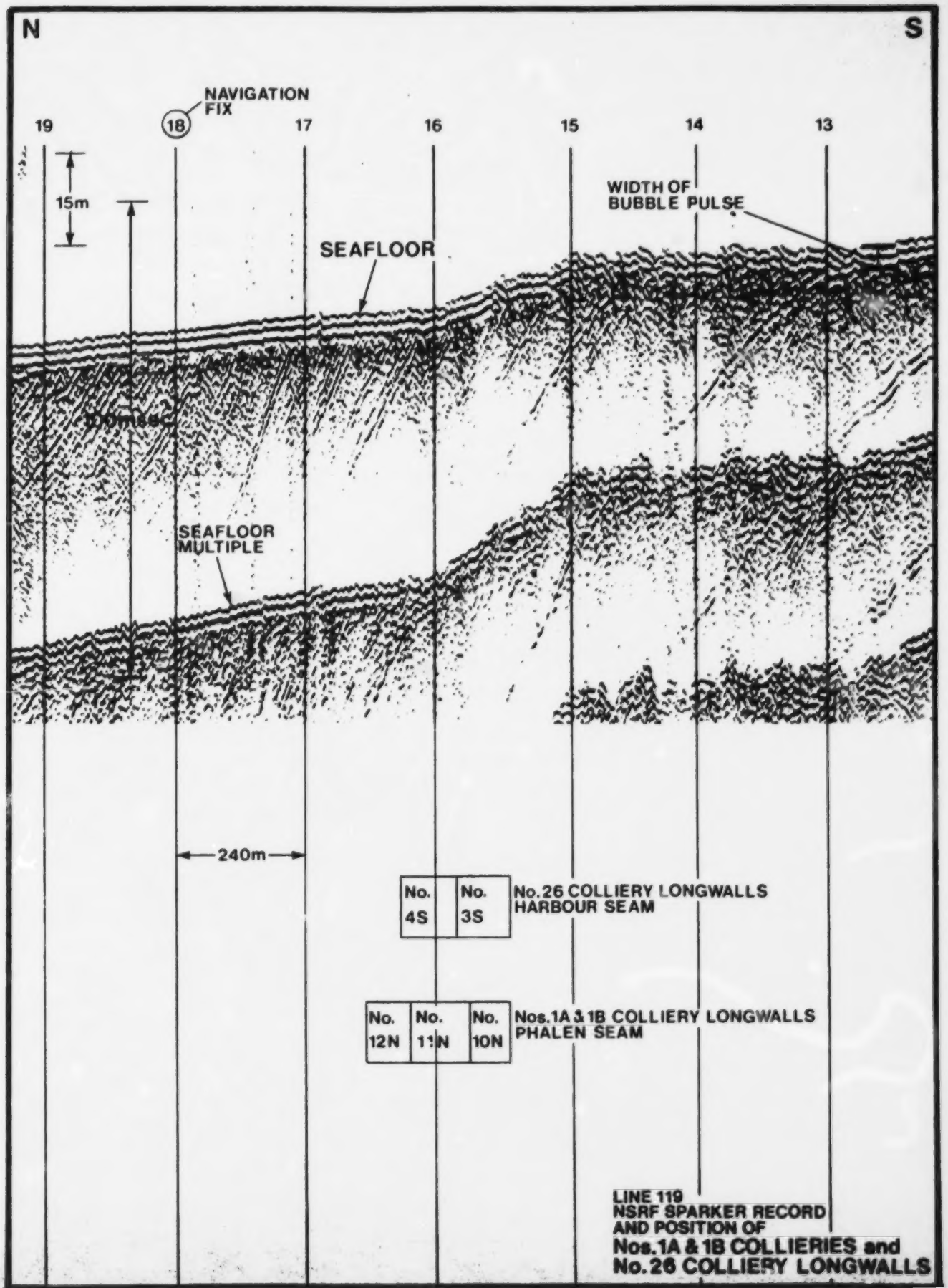
The following section presents two examples of sparker records and their corresponding longwall panels from Map Area 4 (Enclosure 4). This map area, located 3 km to 7.5 km north of Glace Bay contains 2 sites of longwall mining. These are: A) the No. 26 Colliery - Harbour Seam and B) Nos. 1A and 1B Colliery - Phalen Seam.

Description: Figure 19

Figure 19 shows a NSRF sparker profile from Line 119. This record was collected at a sweep speed of 500 msec. The seafloor profile has a vertical exaggeration of 11:1. A bubble pulse approximately 4 msec (5 m) masks the shallow subsurface geology. The seafloor on this record is characterized by a slightly irregular northward dipping plane with a local increase in slope between Fixes 15 and 16. Subsurface reflectors display an apparent dip of 5° N along this line.

Beneath this record is a schematic representation of the Nos. 1A, 1B Colliery (Phalen Seam) and No. 26 Colliery (Harbour Seam) longwalls.

The slope change identified on the seismic record between Fixes 15-16 appears to coincide with the superposition of the Harbour No. 3S, 4S and Phalen No. 10N, 11N longwalls. This is the only anomalous feature along this line. The occurence of this anomaly at the same location as the longwalls may be coincidental and not subsidence-related.


N
S
NAVIGATION FIX
19
18
17
16
15
14
13
15m
WIDTH OF BUBBLE PULSE
SEAFLOOR
SEAFLOOR MULTIPLE
240m
No. 4S
No. 3S
No.26 COLLIERY LONGWALLS HARBOUR SEAM
No. 12N
No. 11N
No. 10N
Nos.1A & 1B COLLIERY LONGWALLS PHALEN SEAM
LINE 119
NSRF SPARKER RECORD
AND POSITION OF
Nos.1A & 1B COLLIERIES and
No.26 COLLIERY LONGWALLS

Description: Figure 20

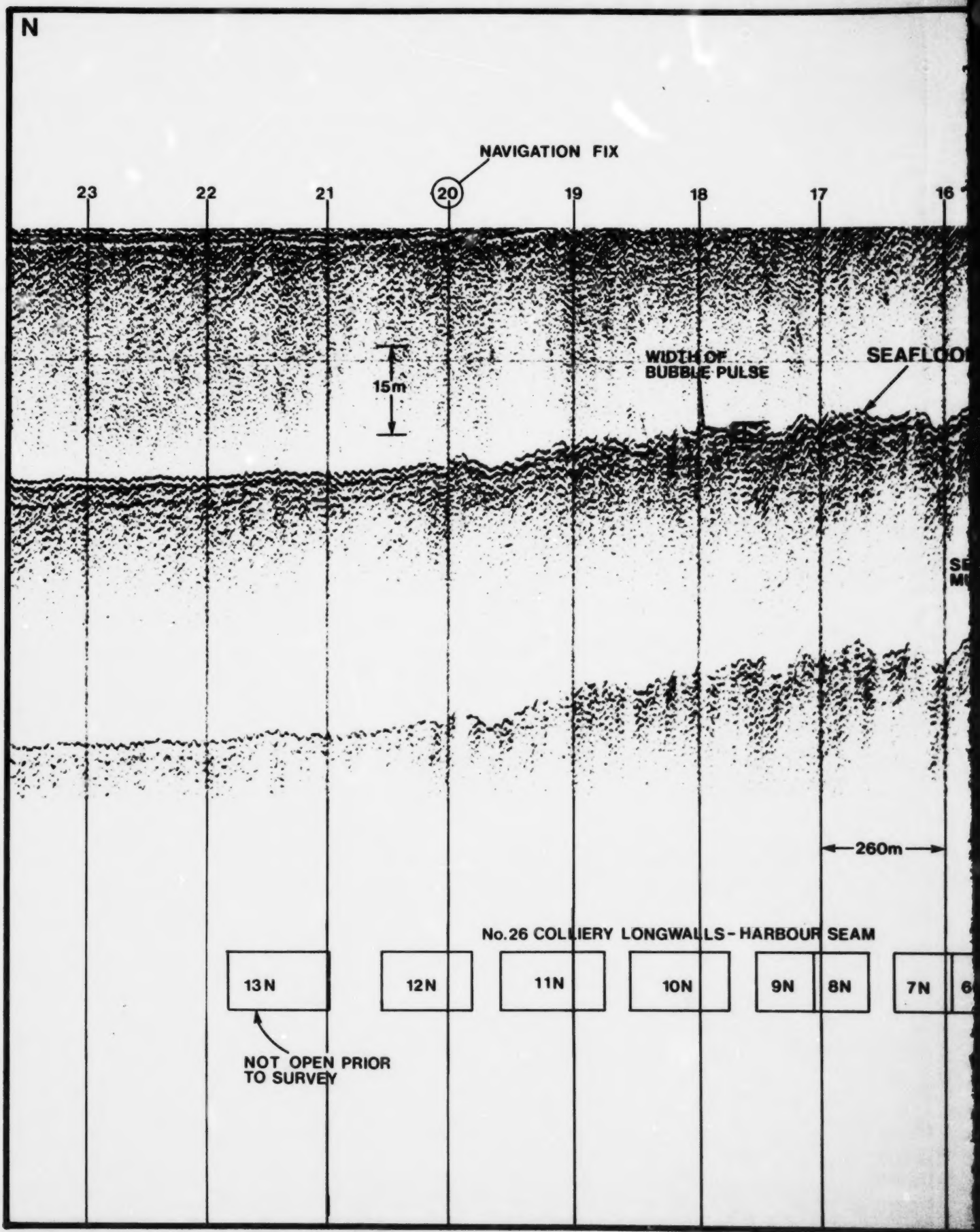
The NSRF sparker profile from Line 117 is presented in Figure 20. This record was collected at a sweep speed of 500 msec. The seafloor profile has a vertical exaggeration of 11.5:1. A bubble pulse approximately 4 msec (5 m) in length masks the shallow subsurface geology. The seafloor is characterized by an irregular, northeastward-dipping plane interrupted by two sediment ponded bedrock depressions.

Below this record is a schematic representation of the Nos. 1A, 1B Colliery (Phalen Seam) and No. 20 Colliery (Harbour Seam) longwalls.

Anomalous seafloor troughs occur on the seismic record between Fixes 13.75-15 and 10-12. The former trough appears to coincide with the superposition of the Harbour No. 3N and Phalen No. 6N longwalls. The maximum depth of this trough, centred at Fix 14.5, is 10 m below the level of the surrounding seafloor. The other trough coincides with a zone of room and pillar mining outside the study area.

Away from these troughs the irregular northward-dipping seafloor displays variations of up to 3 m. There does not appear to be any coincidence of these smaller irregularities with the numerous No. 26 Colliery longwalls in the subsurface. Theory would predict that the seafloor appear as a sinusoidal surface though in practice one might expect to observe a single broad depression resulting from coalescence of numerous subsidence profiles.

On the basis of these observations it is once again concluded that no consistent correlation can be observed between seabed morphology and longwall positions on this line.


N
NAVIGATION FIX
23
22
21
20
19
18
17
16
15m
WIDTH OF BUBBLE PULSE
SEAFLOOR
260m
No.26 COLLIERY LONGWALLS - HARBOUR SEAM
13N
12N
11N
10N
9N
8N
7N
NOT OPEN PRIOR TO SURVEY

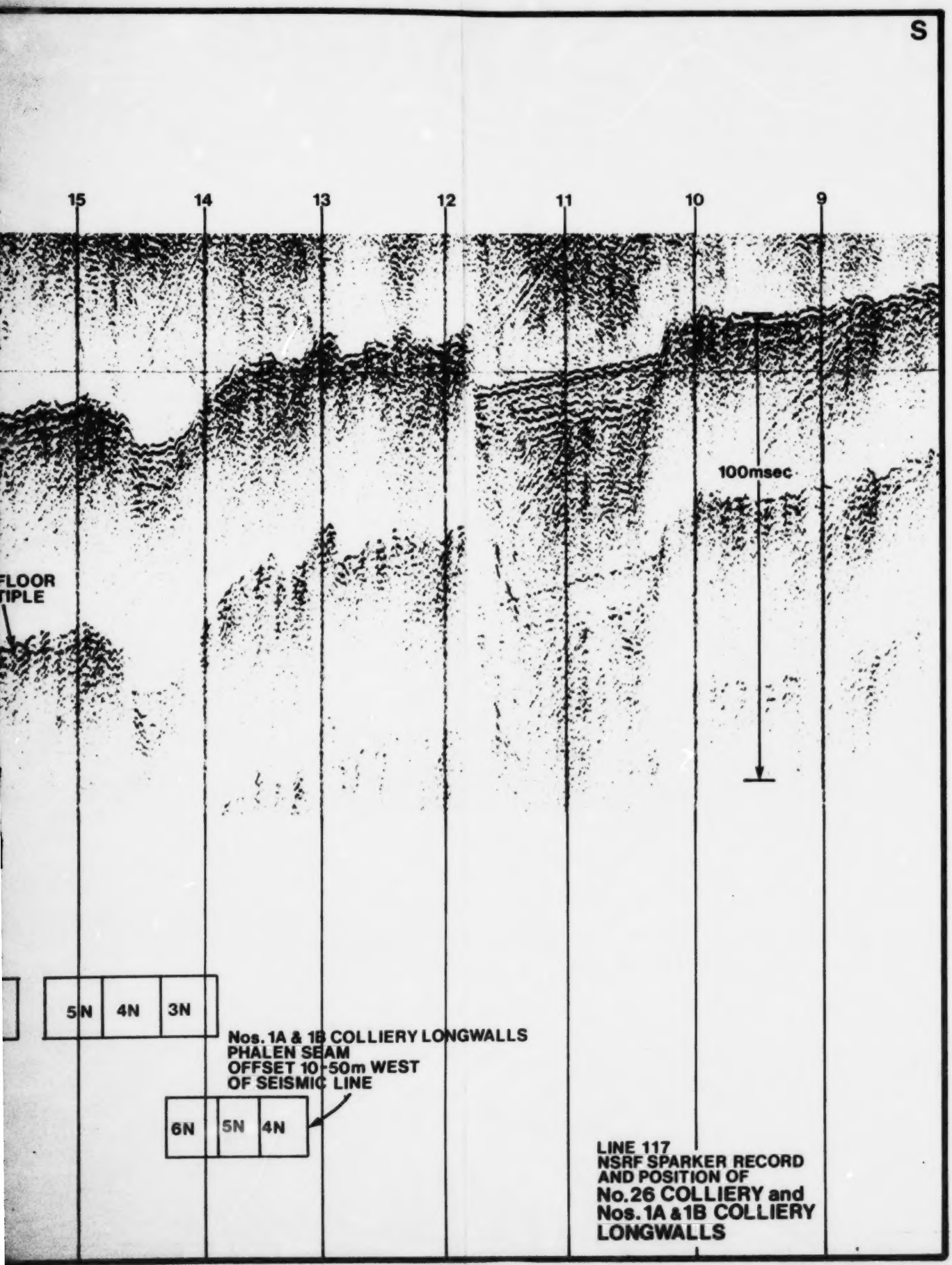

S
15
14
13
12
11
10
9
100msec
FLOOR
TIPLE
5N
4N
3N
Nos. 1A & 1B COLLIERY LONGWALLS
PHALEN SEAM
OFFSET 10-50m WEST
OF SEISMIC LINE
6N
5N
4N
LINE 117
NSRF SPARKER RECORD
AND POSITION OF
No. 26 COLLIERY and
Nos. 1A & 1B COLLIERY
LONGWALLS

FIGURE 20

8.5 Map Area 5

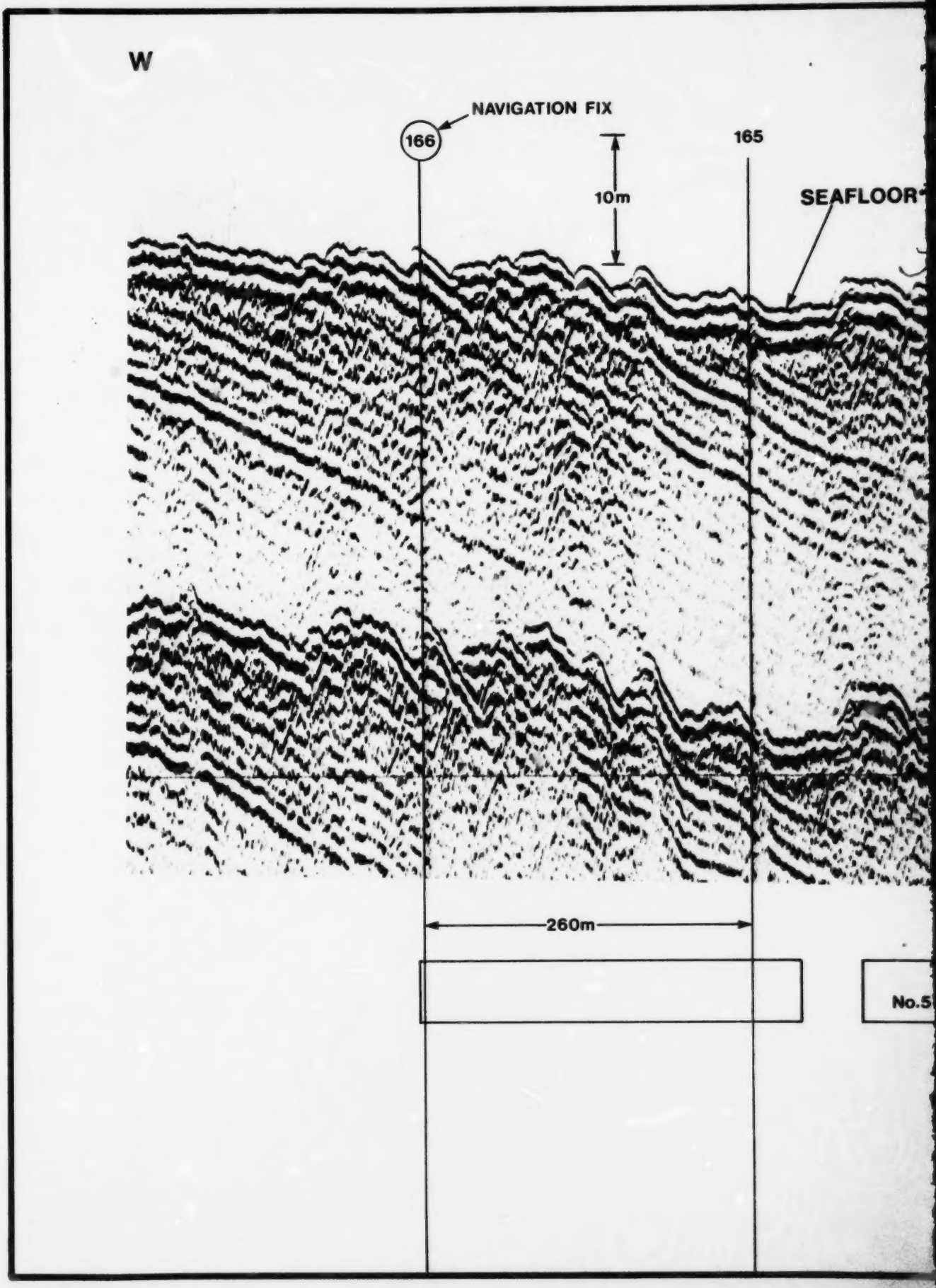
The following section presents three examples of sparker profiles, superimposed with underlying longwall panels from Map Area 5. This map area occurs 0.75 km to 10.5 km offshore of the Glace Bay-Donkin coastline. Two levels of longwall mining occur at this site: A) No. 20; Harbour and B) No. 4; Phalen (Enclosure 5).

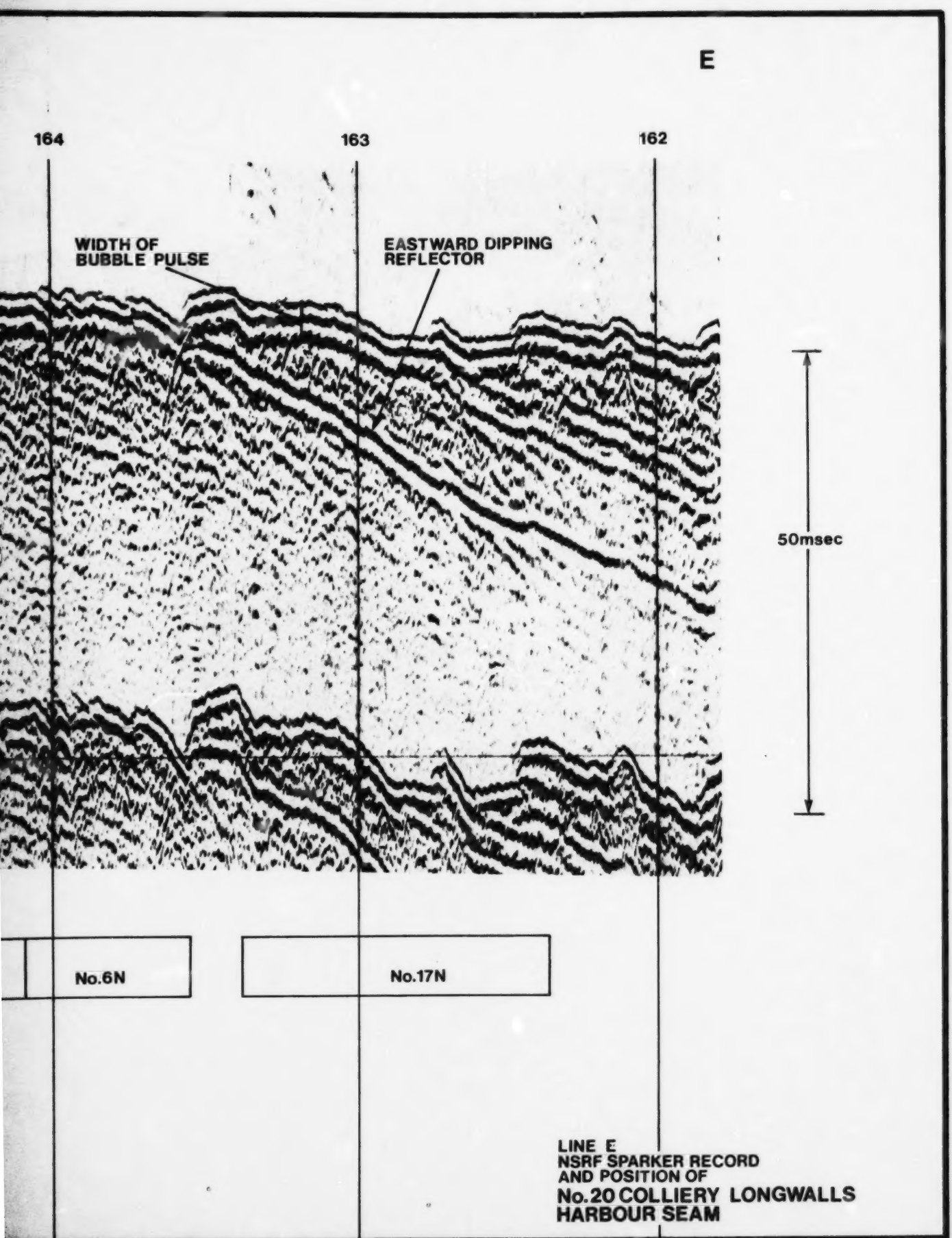
Description: Figure 21

Figure 21 shows a NSRF sparker profile from Line E. This record was collected at a sweep speed of 250 msec. The seafloor profile has a vertical exaggeration of 9.4:1. A bubble pulse approximately 4 msec (5 m) in length masks the shallow subsurface geology. Outcropping of northeastward-dipping strata probably produces the rough seafloor morphology displayed here.

Beneath this record is a schematic representation of the No. 20 Harbour Colliery longwalls.

Two minor seafloor depressions occur on the seismic record between fixes 162.5-163 and 164.7-165.3. These depressions appear to approximately coincide with the position of two Harbour Seam longwalls. In contrast, a slight seabed ridge occurs between Fix 163.5-164.5 coincident with the position of the third Harbour longwall. Because both positive and negative bathymetric features occur along this line above the longwall panels, a correlation of the depressions as subsidence profiles is not supported.


W
NAVIGATION FIX
166
165
10m
SEAFLOOR
260m
No.5



LINE E
NSRF SPARKER RECORD
AND POSITION OF
No.20 COLLIERY LONGWALLS
HARBOUR SEAM

FIGURE 21

Description: Figure 22

The NSRF sparker record from Line 3.0 is presented on Figure 22. This record was collected at a sweep speed of 250 msec. The seafloor profile has a vertical exaggeration of 1:12.2. A bubble pulse approximately 4 msec (5 m) in length masks the shallow subsurface geology. The roughness of the seafloor on this record is likely caused by the outcropping of more resistant strata within the northeastward-dipping bedrock sequence.

Beneath this record is a schematic representation of the No. 4, Phalen and No. 20, Harbour Colliery longwalls.

The anomalous seafloor trough occurring on the seismic record between fixes 9.25 and 11 appears to coincide with the superposition of the Harbour No. 5, and 6S and the Phalen No. 22E, 23E longwalls. The maximum depth of the trough, centred at Fix 10.25, is 3.0 m below the level of the surrounding seafloor. An evaluation of the potential subsidence feature identified here, and on the adjacent Line 3.25, are given in Section 9 with theoretical subsidence modelling results.

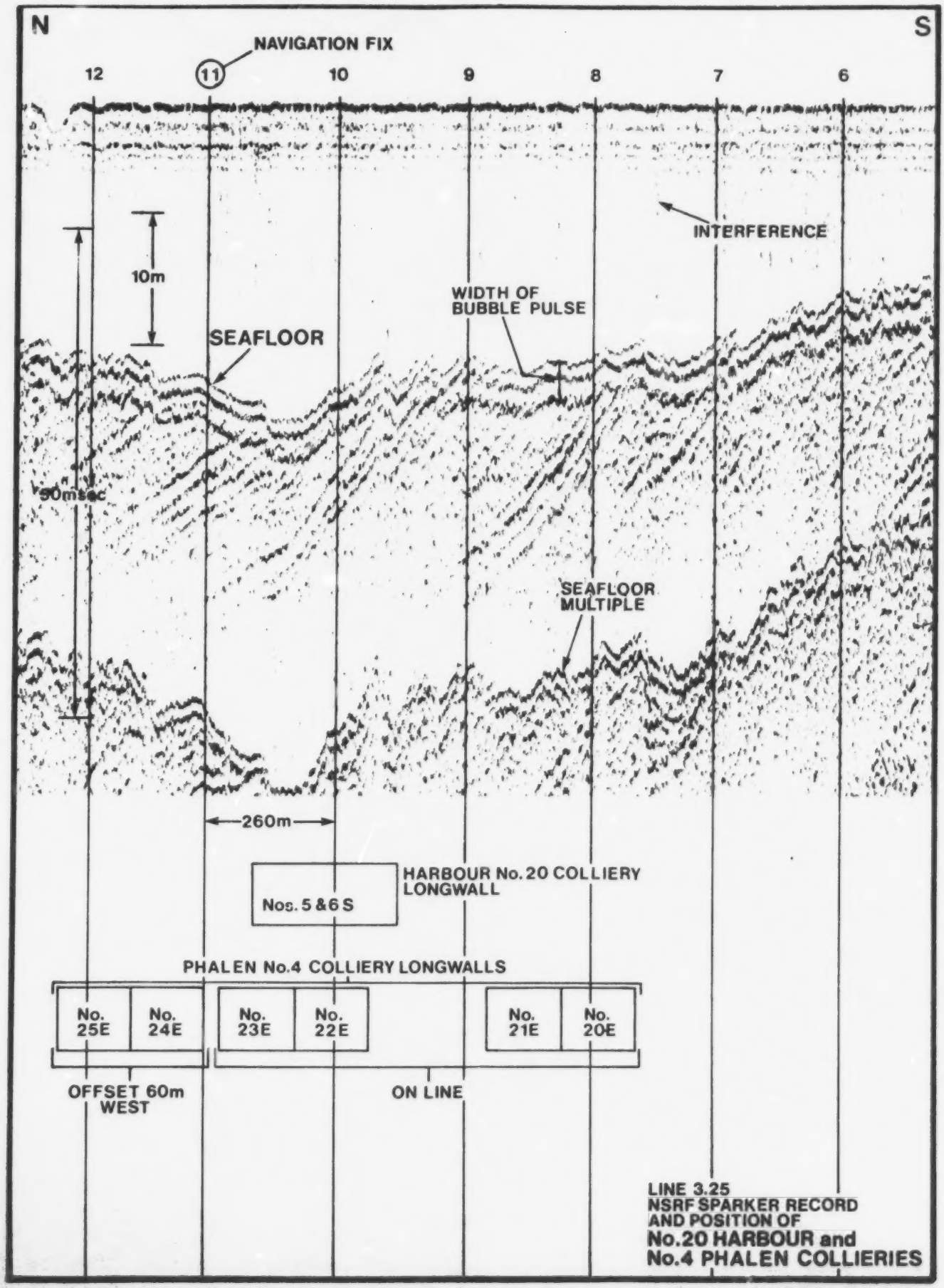

N
S
NAVIGATION FIX
12
11
10
9
8
7
6
INTERFERENCE
10m
WIDTH OF
BUBBLE PULSE
SEAFLOOR
50msec
SEAFLOOR
MULTIPLE
260m
HARBOUR No. 20 COLLIERY
LONGWALL
Nos. 5 & 6 S
PHALEN No.4 COLLIERY LONGWALLS
No.
25E
No.
24E
No.
23E
No.
22E
No.
21E
No.
20E
OFFSET 60m
WEST
ON LINE
LINE 3.25
NSRF SPARKER RECORD
AND POSITION OF
No.20 HARBOUR and
No.4 PHALEN COLLIERIES

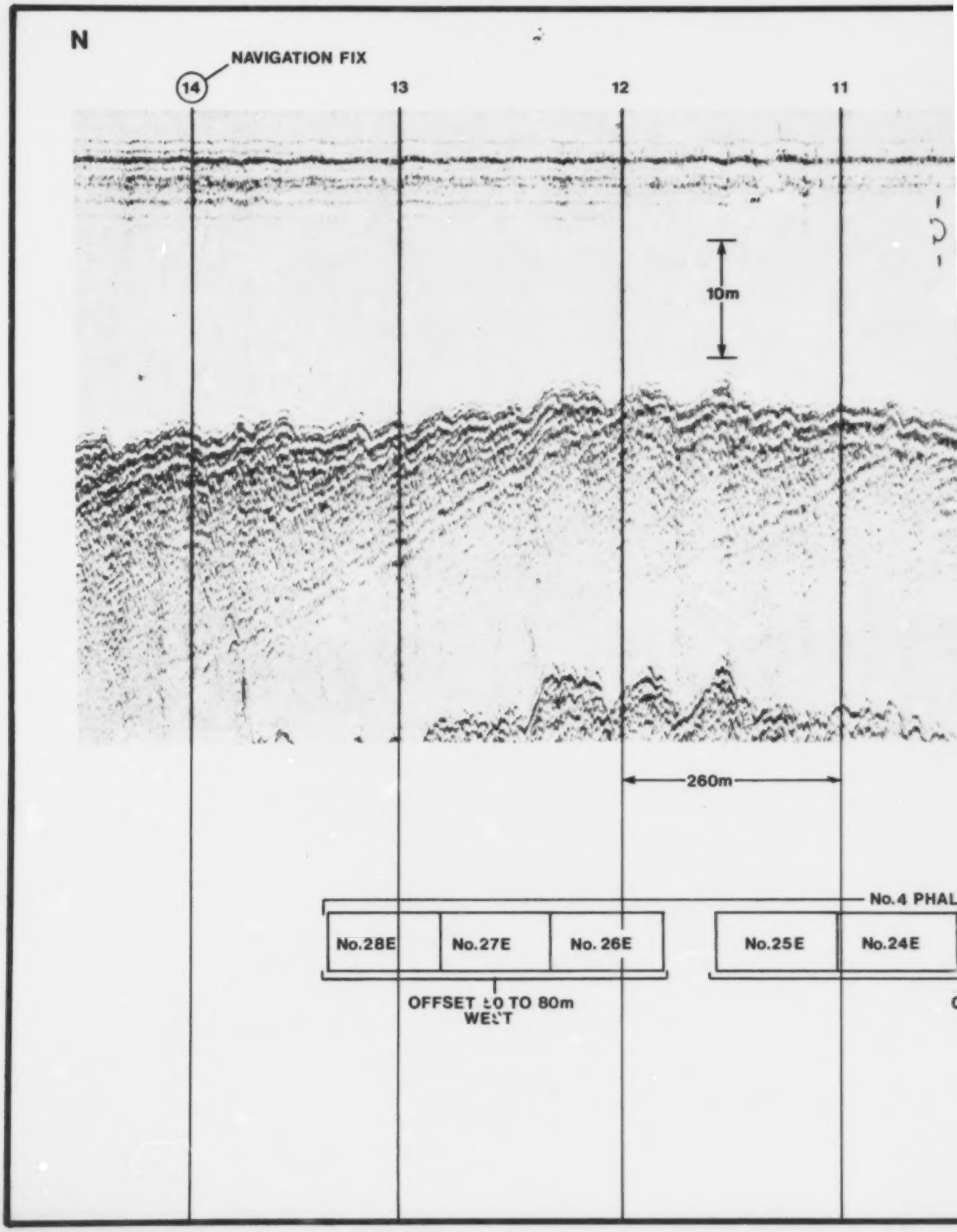
FIGURE 22

Description: Figure 23

Figure 23 shows a NSRF sparker record from Line 3.25. This record was collected at a sweep speed of 250 msec. The seafloor profile has a vertical exaggeration of 1:24.8. A bubble pulse approximately 4 msec in length (equivalent to 5 m, with bedrock velocity of 2500 m/sec) masks the shallow subsurface geology. The irregularity of the seafloor likely results from outcropping of northeastward-dipping strata.

Beneath this record is a schematic representation of the No. 4, Phalen and No. 20, Harbour Colliery longwalls.

The anomalous seafloor trough occurring on the seismic record between Fixes 10 and 11 appears to coincide with the superposition of the Harbour No. 5 and 6S and Phalen No. 22E, 23E longwalls. This coincidence is also noted on the adjacent line 3.0. The maximum depth of this trough, centered at 10.5, is 4.0 m below the level of the surrounding seafloor. An evaluation of this potential subsidence feature is presented in Section 9 along with theoretical subsidence modelling results.


N
NAVIGATION FIX
14
13
12
11
10m
260m
No.4 PHAL
No.28E
No.27E
No. 26E
No.25E
No.24E
OFFSET 50 TO 80m
WEST

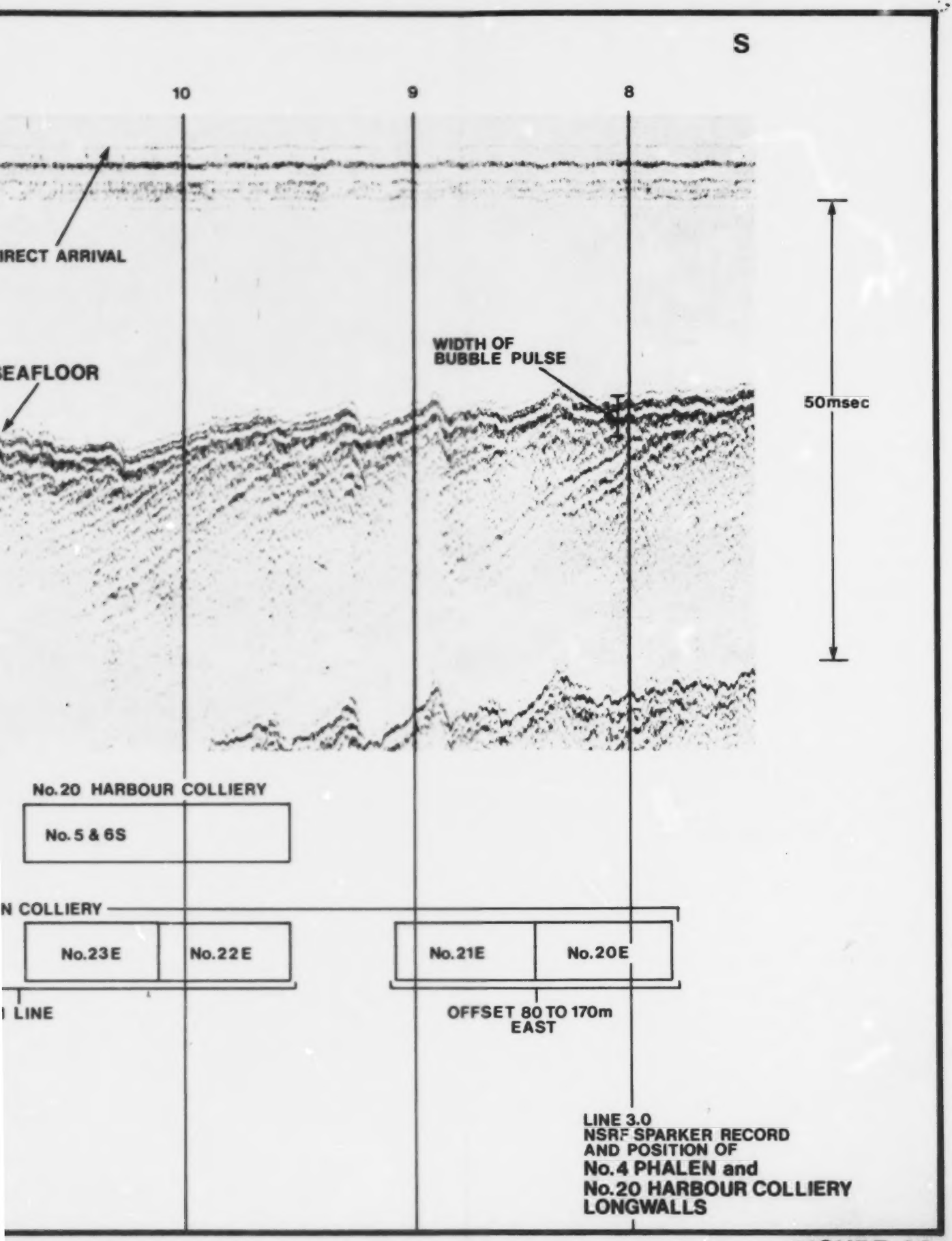

S
10
9
8
IRECT ARRIVAL
EAFLOOR
WIDTH OF
BUBBLE PULSE
50msec
No.20 HARBOUR COLLIERY
No. 5 & 6S
N COLLIERY
No.23E
No.22E
No.21E
No.20E
I LINE
OFFSET 80 TO 170m
EAST
LINE 3.0
NSRF SPARKER RECORD
AND POSITION OF
No.4 PHALEN and
No.20 HARBOUR COLLIERY
LONGWALLS

FIGURE 23

SECTION 9

THEORETICAL MODELLING

Only two of the thirteen geophysical profiles which transect the location of longwall mines as presented in the previous section, display indications of coincident subsidence. These two geophysical profiles, collected adjacent to each other in Map Area 5, are compared here along with their theoretical subsidence model profiles. This modelling was undertaken with the objective of evaluating the appropriateness of these models in predicting potential seafloor strain. The subsidence modelling was subcontracted to Associated Mining Consultants Limited (AMCL) of Calgary. Appendix 3 provides a Modelling Report further describing these calculations.

The geophysical profiles used (NSRF Lines 3.0 and 3.25) were collected over the No. 4 Phalen and No. 20 Harbour Collieries (Enclosure 1). These profiles were selected on the basis of data quality and perpendicularity of the lines to the longwall panels and on the presence of superimposed, double seam extraction.

As described in the previous sections, NSRF Line 3.0 displays a seafloor trough between Fixes 9.25 and 11 which coincides with the occurrence of the Harbour No. 5 and 6S and Phalen No. 22E and 23E longwalls (Figure 22). The maximum depth of this trough, centered at Fix 10.25, is 3.0 m below the level of the surrounding seafloor. The theoretical subsidence model calculated for this line predicts a 2.3 m deep trough at the same location. It also predicts a smaller (1.03 m) depression above the No. 25E and 24E longwalls. However, this smaller depression cannot be distinguished on the geophysical profile.

The second geophysical record, NSRF Line 3.25, displays a pronounced seafloor trough between Fixes 10 and 11 (Figure 23). This depression coincides with the superposition of the Harbour No. 5S and 6S and Phalen No. 22E and 23E longwalls and has an axial depth of approximately 4.0 m below the level of the surrounding seafloor. The theoretical subsidence profile for this section

displays a similar but shallower trough (axial depth 2.16 m), slightly offset from these longwalls. Theoretical results also predict a second subsidence trough (axial depth 0.9 m) above the Phalen Nos. 21E and 20E longwall which is not evident on the geophysical profile.

A weak coincidence of the predicted subsidence profiles and the seismic profiles is seen in these examples from a double seam-mined area. The axial depth of the troughs on the geophysical profiles are approximately 25-30% greater than the predicted values. This would suggest a seafloor strain which is actually greater than the current subsidence model predicts. However it is not certain that subsidence is the cause of these troughs. The lack of detectable subsidence on geophysical profiles from single seam mining areas makes the subsidence explanation tenuous. As seen in the previous section, numerous examples exist where subsidence caused by longwall mining is not apparent on the seafloor or beneath it. This lack of consistency suggests that the depressions observed to overlie longwall mines owe this coincidence to mere chance.

SECTION 10

CONCLUSIONS

The evidence presented in the previous sections demonstrates that subsidence effects cannot be evaluated from the Sydney Coalfield archival geophysical data. However, it should now be apparent that examination of the echo-sounding and seismic profiles of this review for evidence of seafloor subsidence could not possibly be conclusive for lack of reference profiles acquired prior to mining. Valuable subsidence information may be obtainable from similar data if the limitations of existing data were overcome. This would require four major modifications - namely:

a) the recording of reference profiles prior to longwall mining
b) the layout of survey lines relative to longwall mine projections to optimize subsidence detections
c) the selection of optimum recording scales for the geophysical data
d) the recording of geophysical profiles under optimum sea conditions to minimize sensor motion and acoustic noise.

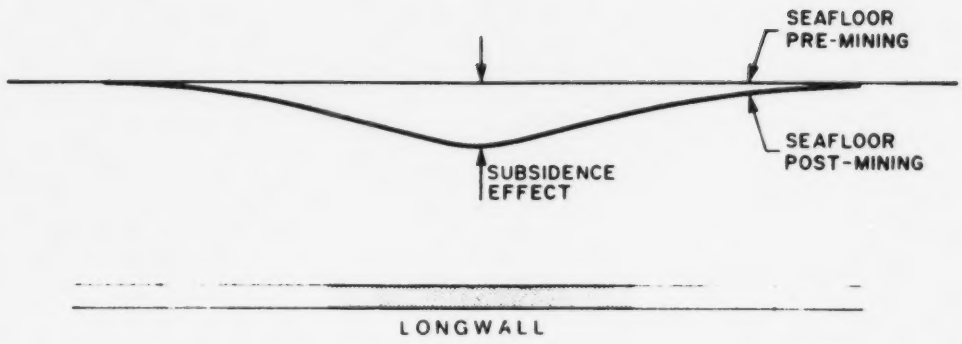
These survey design elements are discussed below.

Reference Profile

The requirement for a pre-mining reference profile is illustrated in Figure 24. In Case 1 the pre-mining seafloor is an idealized, smooth planar bedrock surface. Longwall mining in this case would result in the formation of a seafloor subsidence trough. Such a feature would be easy to recognize, isolate and measure.

Conversely Case 2 demonstrates the more realistic example of an irregular bedrock seafloor surface. Several examples of this type of seafloor have been presented from the Sydney coalfield. Longwall extraction in this case produces the same relative changes in seafloor topography. However, in this case the post-mining seafloor remains irregular precluding the detection of a subsidence trough. In similar fashion, subsidence of a positive seafloor feature could merly produce a less positive seafloor feature.

CASE 1 PLANAR SEAFLOOR



CASE 2 IRREGULAR SEAFLOOR

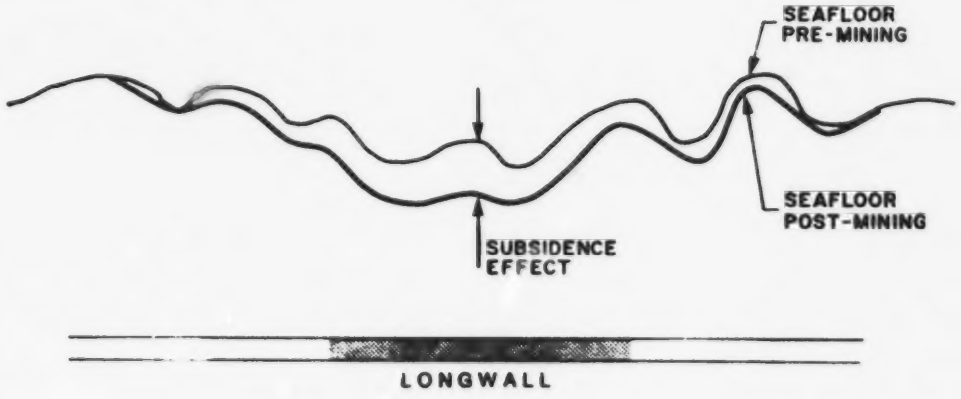


FIGURE 24

In summary, geophysical data cannot be used to evaluate subsidence of a complex seafloor unless the pre-mining seafloor is profiled as the reference datum against which all post-mining measurements are compared. This is probably the critically limiting factor in the current study.

Recording Scales

The second shortfall of the existing data set is that the recording scales are inappropriate for subsidence measurements. Comparing the vertical scales used in the various data sets (below) it can be seen that small changes which must be evaluated (ie. 1 m) are too compressed to be accurately measured from the existing profiles.

NSRF Sparker Records:	1 m	(1/4 sec sweep)
:	1 m	(1/2 sec sweep)
BIO Echosounder:	1 m	(1/8 sec sweep)
Dobrocky Echosounder:	1 m	(Pre-dialed velocity - sweep not applicable)

The same problem exists for the horizontal scales. Recording scales appropriate to subsidence measurement can easily be achieved by increases in sweep speeds and paper speed achievable with the proper equipment.

Noise Levels

The most serious source of acoustic noise identified originates from poor weather and sea conditions. These conditions cause vessel and sensor heave which can distort the seafloor morphology on both the echosounder and sidescan records. Under extreme conditions, such as is seen on the BIO echosounder records, data may be unobtainable. Increased sea state also has a detrimental effect on the quality of seismic profile data.

Although heave compensation systems exist for reducing motion, they have the effect of oversmoothing in areas of rough seafloor. A more appropriate solution to this problem is to restrict any future surveys to fair weather conditions.

Line Positions

The other concern with the archival geophysical data is that most of the lines are oblique to the long-axis of the longwall panels instead of perpendicular to them. This can distort any subsidence effects. Should future geophysical work be conducted, lines should be layed out perpendicular to the longwalls to alleviate this problem.

SECTION 11

RECOMMENDATIONS

11.1 Seafloor Subsidence

Future Survey Design

Three phases of a successful subsidence measurement program using geophysical data are suggested by our study and are presented below.

In the first phase, detailed bathymetry and sub-bottom data must be collected above and as yet unopened, but planned longwall. Possible candidate sites are the newly developing longwall panels at the Lingan, Prince or Phalen Collieries. The Donkin mine, if it proceeds, would be another candidate. Field measurements of subsidence should be replicated at as many sites as possible.

Upon extraction of a longwall panel a second phase survey would be conducted, repeating the original survey lines precisely. Identical data acquisition equipment, recording parameters, shooting geometry, navigation etc. should be employed. Because the time between these two surveys would probably be 1 to 2 years, accurate documentation of the field work must be completed after each survey.

In the final phase, subsidence could be evaluated by measuring the changes in seafloor morphology which have resulted from longwall mining. This could be done in at least two ways.

One possibility is to simply reproduce the lines on film, overlay the records and measure the changes. A more elaborate method would be to digitally record and plot the corrected bathymetry in computer generated pre- and post-mining block diagrams. The background topography could then be filtered out leaving the subsidence anomaly. In either case the subsidence could be measured and values contoured.

Site Selection

To be certain changes in seafloor morphology result from longwall mining, the survey site should have bedrock exposed. If sediment is present, redistribution of sediment may diminish and mask the subsidence profiles. Although this could be overcome with sub-bottom profiling systems. Areas of bedrock outcrop are typically stable and any changes in morphology could be related directly to mining-induced subsidence.

Positioning; Onshore Control

Previous workers have noted that coastal erosion has destroyed many of the bench marks along the Sydney-Glace Bay coastline. This would require a shoreline benchmark survey prior to any offshore subsidence program. The conventional traversing technique would provide coordinates with positional accuracy of less than 1 m. Stations would be surveyed to provide the best possible geometry between the offshore survey site and the onshore transponder stations.

Positioning-Offshore Control

A Del Norte Trisponder, Motorola Mini Ranger or more accurate positioning system is recommended for navigation. Distance is measured with this system by translating the time it takes the signal to travel from the master unit onboard the survey vessel to the onland stations. Trisponder and Mini Ranger ranging accuracy is of the order of 1 m at the ranges anticipated. Accuracy can be improved by increasing the number of well-positioned onland stations. The best positioning geometry occurs when the acute angle between the master unit and shore stations is between 60° and 120°. Trisponder and Mini Ranger is generally not effected by moderate rain and fog.

To accompany this hardware we recommend an onboard computer, plotter and interface unit and "state-of-the-art" navigation software. This system would provide real-time positioning and plotting of the survey-lines, thus improving onboard quality control.

Depth Measurement System

The Krupp Atlas Deso 20, or an equivalent accurate survey sounder is recommended here. This two component compact system, which has digital or analogue output, uses dual (high and low) frequencies for measuring water depth. The system operates by emitting short bursts of sound directed vertically downward. These are reflected by the seafloor and return to the sounder as an echo. The time between the transmission of the signal and the return of its echo is a measure of the depth. The speed of sound in water at the survey site would be measured with the bar check procedure and input into the Deso digitally. Similarly, transducer draught would be programmed into the sounder and corrected for automatically.

There are a number of error sources involved in depth measurements using any echosounder. These include:

1) location of reflection
2) wave motions
3) velocity of propagation and
4) tides and water levels.

These respective errors would be reduced by:

1) using a narrow beam sounder
2) restricting surveys to calm sea periods
3) calibrating velocity on site and
4) utilize predicted tide data and on site tide measurements in data reductions.

Sub-bottom Profiling

The surface towed O.R.E. Geopulse System is recommended here to provide high resolution, sub-bottom information. This system is light, easily operated and highly compact. It's high power (three times the acoustic energy of conventional systems) and increased resolution make it appropriate for this project. The Geopulse System consists of five components including:

A) Acoustic Source
B) Acoustic Receiver/Amplifer
C) Power Supply
D) Hydrophone Array
E) Recorder.

This system would be used in testing survey sites for bedrock exposure and evaluating bedrock characteristics (ie: microfaulting, jointing, dip).

Survey Vessel

McGregor recommends the use of a local vessel from Sydney Harbour (or nearby). This vessel must be a good sea boat, 12-14 m in length and have an enclosed cabin. Adequate dry space must be available onboard for the navigation, bathymetric and geophysical instrumentation (including recorders, tranceivers, computer, plotter and analogue tape recorder). The deck space must be large enough to allow deployment and retrieval of equipment and the running of a generator. Mobilization/demobilization of this type of survey vessel is relatively uncomplicated.

11.2 Bedrock Integrity

The recognized concern in the Sydney Coalfield is that the extent and severity of rock mass deformation above mined longwall panels is unknown. Previous workers (and this project) have emphasized the use of seabed strain and subsidence to define "safe" mining conditions. However, there may exist alternative methods to more directly measure subsidence.

The first alternative approach would employ changes in seismic reflection or refraction velocities and relate these to strata deformation. Such work may be possible in an area of simple structural geology and limited lateral facies changes. Preliminary work on seismic source receiver characteristics, possible shooting geometry and geological conditions could be conducted to test the feasibility of such a project.

Secondly, recent advances in fracture/strength logs (Halker et. al., 1986) may provide an opportunity for direct deformation measurement. This method, detailed in the aforementioned reference, could be used by boring and logging vertically upward from within a mined panel. These log results could be compared to logs obtained away from the mined panels. A feasibility study of this technique is recommended here.

REFERENCES

AMCL-Kilborn. 1981. Donkin-Morien Development Project. Submitted to Cape Breton Development Corporation.

AMCL. 1984. "Ground movement, land based instrumentation and design criteria aspects of seabed monitoring of mining subsidence" Section 4 in A Review and Evaluation of Potential Collection Methods for Monitoring Subsidence Over Longwall Workings in Submarine Coalfields. CANMET Report, DSS File No. 23SQ.23440-3-9031, Volume 1.

Calder, J. H. 1985. Coal in Nova Scotia. Nova Scotia Department of Mines and Energy, pp. 79.

CANMET. 1985. Potential Instrumentation Schemes for Monitoring Seafloor Subsidence. Energy Research Program. Coal Research Laboratiries Division Report ERP/CRL 85-26 (OP) 19, pp. 20.

Dobrocky Seatech Ltd. 1984. Monitoring Program for the Donkin-Morien, Lingan-Phalen Coal Mines. Submitted to Cabe Breton Development Corporation, pp. 94.

Geoterrex Ltd. 1980. Marine Bottom and Sub-bottom Survey by Geophysical Methods on Site Located Offshore Sydney, Nova Scotia. Submitted to Cape Breton Development Corporation, pp. 65.

Halker, A., N. J. Kusznir, D. W. Mellor and K. R. Whitworth. 1986. The Synthesis of Fracture/Strength Logs Using Borehole Geophysics: A New Geotechnical Service. In Coal Geophysics, Geophysics reprint series No. 6, Society of Exploration Geophysicists. Ed. D. J. Buehanan and L. T. Jackson, p 52-64.

Jacques, Whitford and Associates Ltd. 1984. A Review and Evaluation of Potential Data Collection Methods for Monitoring Subsidence Over Longwall Workings in Submarine Coalfields. CANMET Report, DSS File No. 23SQ.23440-3-9031, Volumes 1 and 2.

Nova Scotia Research Foundation Corporation. 1979. Report 6-79, Donkin and New Waterford Seismic Reflection Survey. Submitted to Cape Breton Development Corporation, pp. 27.

APPENDIX 1

DATA INVENTORY

1) Map Area 1 - No. 4 Phalen Seam and No. 20 Harbour Seam Collieries

NSRF - Seismic Records

LINES: 1.0, 1.5, 2.0, 2.5, 2.75, 3.0, 3.25, 3.5, 4.0
LINES: KK, LL, MM
LINES: C, D, E, F, G, H
LINES: D1, D2, D3, D4, D5, D6

DOBROCKY SEATECH LTD. - Echosounder Records

LINES: GB-1, 2, 3

2) Map Area 2 - No. 1A and 1B Collieries (Phalen Seam) and No. 26 Colliery (Harbour Seam)

NSRF - Seismic Records

LINES: 116 through 119 (inclusive)
LINE: 1.5
LINES: KK, LL, MM
LINES: C, D, E

DOBROCKY SEATECH LTD. - Echosounder Records

LINES: 1B-1, 2, 3

BEDFORD INSTITUTE OF OCEANOGRAPHY - Echosounder, Sidescan and Seismic Records

FIXES: 3061550 to 3061609 (inclusive)

3) Map Area 3 - No. 16 Colliery (Phalen Seam) and
No. 12, 14 Collieries (Harbour Seam)

NSRF - Seismic Records

LINES: 110 through 115 (inclusive)
LINES: JJ, KK, LL

DOBROCKY SEATECH LTD. - Echosounder and Sidescan Records

LINES: LP-8, 9, 10, 12, 14, 16, 18, 20, 22, 24, 26

BEDFORD INSTITUTE OF OCEANOGRAPHY - Echosounder, Sidescan and Seismic Records

FIXES: 3061610 to 3061840 (inclusive)

4) Map Area 4 - Princess and Florence Collieries (Harbour Seam)

NSRF - Seismic Records

LINES: 104 through 109 (inclusive)
LINES: KK, JJ, LL

DOBROCKY SEATECH LTD. - Echosounder Records

LINES: SH1, SH2, SH3

5) Map Area 5 - Prince Colliery (Hub Seam)

NSRF - Sparker Records (Acquired prior to mining)

LINES: 101, 102
LINES: CC, DD, EE

DOBROCKY SEATECH LTD. - Echosounder and Sidescan Records

LINE: PA-1 (Data north of Fix 6 acquired prior to mining)

BEDFORD INSTITUTE OF OCEANOGRAPHY - Echosounder, Sidescan and Seismic Records

FIXES: 3061952 to 3062118

Original Track Plots

The original scales and projections of the three data sets vary greatly. The NSRF track plots are plotted at 1:25,000 on a metric Devco Grid. The Dobrocky data are also at 1:25,000 but with a Universal Transverse Mercator projection. The Bedford Institute of Oceanography data were supplied at 1:4,800 but are restricted to a Lambert Conformal projection.

APPENDIX 2

OPERATION SUMMARIES

APPENDIX 2

OPERATION SUMMARIES

The equipment descriptions presented here have been modified from the cited contractors operation summaries. Additional sections on data quality and recording parameters are included here.

NOVA SCOTIA RESEARCH FOUNDATION (1978)

Acoustic Data

A Teledyne "line-tip" spark array was deployed as the acoustic source for this survey. This source was powered at 200 Joules and fired at 2 or 4 times a second to generate the seismic signal. One of two 20-foot hydrophone arrays, (Aquadyne or Recon) were utilized as receivers. Signal filtering and amplification was done by a NSRF unit and the final graphic display of profiles was on a 4600 or 4100 EPC recorder.

Positioning Systems

A Del-Norte Trisponder system was used for fixing the position of the boat while on survey lines. The operation principle of this system has been described in the previous section.

Four shore stations were utilized for most of the survey. However on occasion, only two of the shore stations were available. The result of this is that some lines are in two or three sections.

Survey Vessels

Two boats were used on different phases of the survey. The Prince Colliery area was done from the "Sandra", a 40-foot Cape Island style vessel belonging to a local diving company.

The Donkin and New Waterford areas were surveyed from the "Ceithir Nigean-an", also a local Cape Islander.

Recording Parameters

The majority of the data acquired by NSRF (Map Areas 1 - 4) were collected at a 500 msec sweep speed. Exceptions to this exist in Map Area 5 area where data are recorded at a 250 msec sweep speed. The latter sweep speed increases the vertical exaggeration and although not optimal, was preferred over the former for the purposes of this project.

Data Quality

The quality for this data set ranged from fair to good mostly as a function of weather. The seafloor and the shallowest subsurface geology tend to be masked by a broad "bubble-pulse" (approx. 4 msec or 5 m) inherent in the profiling system.

The isopach maps of surficial sediment available for the Sydney Coalfield (AMCL-Kilborn Report (1981), Jacques Whitford and Associates (1984)) have been contoured from digitized values supplied in the NSRF (1979) report (map numbers 2457-3 and 2457-4). In the opinion of the geologists and geophysicists at McGregor GeoScience the seismic records from which these values have been obtained have been misinterpreted by the NSRF Geophysics Division in the area of subsidence modelling. No time was allocated in this project to correct these errors. Future use of these maps should be undertaken with consideration for these discrepancies.

DOBROCKY SEATECH LTD. (1984)

Acoustic Systems

Sidescan Sonar System

An O.R.E. sidescan sonar was used to obtain two-dimensional acoustic images of the seabed. The sidescan sonar system consisted of the following major components:

1) O.R.E. 160A deck unit transceiver
2) O.R.E. 162 sub-sea transceiver
3) O.R.E. 159 tow fish
4) E.P.C. 3200S graphic recorder
5) SEA-MAC 1000 winch

The sidescan sonar fish was deployed over the stern of the survey boat. The fish was normally towed at 20 m above the seabed, but ranged from 10 to 30 m above the seabed. The distance the fish was towed behind the boat, known as layback distance, varied from 10 to 50 m as required by total water depth.

Sidescan sonar signals were recorded on both port and starboard channels at a display sweep of 1/4 sec per channel or approximately 187 m slant range per channel.

Survey Echosounder

The echosounder system consisted of two major components:

1) Raytheon DE-7192 Transducer
2) Raytheon SSD-100 Digitizer

The manufacturer's quoted depth accuracy of better than 0.1 m for depths shallower than 20 m, and better than 0.25 m for depths of 50 m. Paper advance speed was either 2.5 or 3.0 cm/minute. Speed of sound adjustment was set at a constant reference value of 1463 m/s.

The echosounder transducer was mounted midship on the port side of the survey vessel. The transducer depth was maintained at approximately 0.6 m below the water line throughout the survey.

Positioning System

Positioning was achieved using an automated surveying package consisting of:

1) Del Norte trisponder positioning system
   - Distance measuring unit (DMU)
   - Two master transponder units (one spare)
   - Two remote shore transponders
2) Hewlett Packard 9825T computer
3) Hewlett Packard 9872C plotter
4) Interface units, and
5) Navigation system software.

The operation principles of this system are given in Section 11. For a complete breakdown of these components' specifications the interested reader is referred to Dobrocky (1984) p. 6-7.

Survey Vessel

The survey vessel, the KEL KIM, was charted from a local resident. The KEL KIM is a 10 m Cape Islander equipped with radios, radar, an echosounder and Loran-C positioning.

Recording Parameters

The sidescan sonar records were collected with a sweep speed of 250 msec. The echosounder amplifier recorder was tuned with an assumed velocity setting of 1463 m/s during data acquisition.

Data Quality

Data quality of the echosounder records ranged from poor to good with the main inhibitor of data quality being weather. Additional problems in data useability resulted from an inappropriate horizontal scale (excessive compression) which could be overcome with decreased ship speed and/or increased paper speed.

The navigation system used is believed to provide an accuracy of 1 to 3 m along line but may be up to 10 m off either side of the lines. The navigation problems associated with the Dobrocky survey would have to be rectified for future surveys (ie. poor shore based stations at times, only two shore based stations).

The sidescan data were acquired over limited areas only.

BEDFORD INSTITUTE OF OCEANOGRAPHY (1985)

Acoustic Systems

The array of geophysical instruments deployed include:

- Huntec Deep Towed System (DTS)
- AGC Airgun System
- 100 kHz Klein sidescan sonar system.
- 12 kHz echosounder system

Deep Towed System

Huntec data were recorded on an HP3968A tape recorder and simultaneously displayed on two EPC 4600 series recorders. One was used to display an internal LC10 hydrophone and the other an external Benthos Mesh 15/10P streamer. The internal hydrophone was processed through the systems console signal processor module while the external streamer was processed through a Model 3700 Krohn-hite filter.

Airgun System

The AGC airgun seismic reflection system consisted of a control console, a 40 cubic inch Bolt airgun, a Nova Scotia Research Foundation hydrophone streamer equipped with 36 elements and a control console. The airgun was fired every 3 seconds at an air pressure of 1800 psi. Air pressure was supplied by a compressor mounted on the fore deck. The data were recorded on an HP3968A 8-track tape recorder and on to an EPC 1600S graphic recorder.

Echosounder

Bathymetry was collected using the ship's 12 kHz echosounder and recorded continuously on a Raytheon LRS recorder.

Sidescan

Sidescan sonar images were collected using the 100 kHz Klein Model 401 sidescan. These images were displayed on an EPC 4100 graphic recorder.

Positioning System

Ship's positioning was provided by the conventional hyperbolic Racal-Decca Loran-C receiver in conjunction with the single-channel Magnavox 5102 satellite receiver. The positions given by these two receivers were recorded on magnetic tape and output to a Decwriter printer, located in the general purpose lab. All Loran-C positions were logged at 1 minute intervals and satellite positions at every pass. The navigation system used provides positions within 20-50 m (Spradley, 1986).

Survey Vessel

The C.C.S. DAWSON, owned by the federal Department of Fisheries and Oceans, was used in this survey. Her principle statistics are listed below:

TYPE:	Research Vessel
FLAG:	Canadian
OWNER:	Government of Canada
BUILT:	1967
OVERALL LENGTH:	64.5 m
MOULDED BEAM:	12 m
MAXIMUM DRAFT:	4.9 m
DISPLACEMENT:	1940 tonnes
GROSS REGISTERED TONS:	1311 Tons
FULL SPEED:	14 knot
CRUISING SPEED:	10 knot
SCIENTIFIC COMPLEMENT:	13 Persons
LABORATORY SPACE:	87.3 m sq.
ENGINE:	Diesel
ECHOSOUNDERS:	12 kHz
NAVIGATION:	Loran-C
	Magnavox 5102 Satellite Receiver

Recording Parameters

The Huntec DTS System records (internal and external hydrophones) where collected with a sweep speed of 250 msec. The sweep speed with which the bathymetry and airgun records were collected was calculated to be 250 msec and 500 msec, respectively. These sweep speeds were not annotated on these records or given in the operations report. Similarly, the sweep speed used in acquiring the sidescan data was not indicated on the records. The most probable setting is 250 msec per channel.

Data Quality

Data quality ranged from poor to very poor. Gale force weather conditions during the survey were at least partially responsible for this problem. Base on the echosounder records, the transducer was aerated* for approximately 50% of the survey. This resulted in an incomplete seabed trace.

High noise levels, source-receiver heave and inappropriate recording scales have rendered the Huntec DTS and AGC airgun records useless for this study.

In addition to these problems, these data are over compressed horizontally (approximately 5 times the optimal scale) and line positions were run oblique, rather than normal to the mineworkings.

The sidescan data collected was not as affected by weather and as such provide reasonable control on the acoustic reflectivity of the seafloor.

*Aeration results from decoupling of the echosounder transducer with the water as a result of excessive ship heave.

APPENDIX 3

SUBSIDENCE MODELLING REPORT

Associated
Mining Consultants Ltd.

1400, 910 - 7 Avenue S.W., Calgary, Alberta T2P 3N8
Tel: (403) 264-9496 Telex: 03 821201

SUBSIDENCE STUDY - SYDNEY COAL FIELD

APPENDIX

SUBSIDENCE PROFILES

AR-114

JANUARY 1987

APPENDIX
SUBSIDENCE PROFILES

INTRODUCTION

Associated Mining Consultants (AMCL) had responsibility for constructing cross-section and calculating subsidence along the sections chosen by McGregor Geoscience. The area selected lies northeast of the Town of Glace Bay, approximately 3 km north of Macrae Point. McGregor Geoscience chose segments of two sparker survey lines run in 1978 by Nova Scotia Research Foundation and Integrated Survey Systems Ltd. These are:

- NSRF Line 3.00 shot points 6 to 14
- NSRF Line 3.25 shot points 6 to 12

MINING

The selected area has a water depth of about 100 ft. (30 m). Both the Phalen Seam (No. 4 Colliery) and the Harbour Seam (No. 20 Colliery) were mined in this area by 'longwall' methods.

The Phalen Seam (No. 4 Colliery) was mined first between 1951 and 1960. The seam height was about 6 ft. (1.8 m) at an elevation of -1300 ft. to -1900 ft. (-400 m to -580 m) giving a seam gradient of 1:10 northward. 'Longwall' in this mine meant handfilled faces, with shaker-pans for coal clearance until 1956; followed by DOSCO miners with conveyors. Both were advancing "longwalls" in 1,000 ft. (300 m) wide panels, with strip-packing and centre roadways.

The Harbour Seam (No. 20 Colliery) was mined in 1967/68. The seam height was about 6 ft. (1.8 m), 470 ft. (140 m) above the Phalen Seam. Only one 'Longwall' panel extends across this area; it was 1,000 ft. (300 m) wide, cut with a DOSCO miner and was reported to have been fully caved. A centre roadway was carried in this panel until 1966 but the mine plan indicates that it was discontinued in the immediate area of interest.

Mining was completed in this area 10 years prior to the Sparker Survey. A composite extraction height of 12 ft. (3.6 m) was attained between shotpoints 9 and 11 along both NSRF lines.

SEABED SUBSIDENCE

Cross-sections along NSRF Lines 3.00 and 3.25 (see attached) were constructed based on:

- CBDC mine plans scale 1 inch to 400 ft.
- AMCL Seabed Contours, 1981; based on NSRF bathymmetry, 1978
- AMCL Isopach Map Unconsolidated Sediment, 1981; based on NSRF Sediment thickness determination, 1979

The subsidence analysis was carried out by Mr. Charles H. Shadbolt, who was the National Coal Board (NCB) Headquarter's Subsidence Engineer and Deputy Chief Surveyor until his recent retirement.

The subsidence predictions have been carried out using the NCB "Midlands Graphical Model" devised by Mr. Shadbolt. This model consists of a wide ranging collection of normalized transverse profiles together with dynamic profiles and subsidence contours, based on 120 well documented cases in the Midlands Coalfield. The 'Subsidence Engineers' Handbook' and its derivative computer model 'MULPAN' was based on an arithmetic average of 105 UK cases and, therefore, is representative of national average conditions only. The 'Midlands Model' shows far less deviation of individual cases from the normalized curves than the S.E.H. derived model. The Midlands area is considered to be geologically representative of the Sydney Coalfield.

Subsidence, horizontal displacement and strain curves were determined for each seam and summed by superposition for each section (see attached). The summation of horizontal displacements is less applicable in multiple-panel situations and is, therefore, an approximation. The strain and subsidence profiles are more reliable.

The 'longwall' panels in both the Phalen and Harbour Seams are of less than critical width at the mining depth in the area of the sections. The maximum predicted total subsidence of 2.3 m (Line 3.00) from a cumulative extraction height of 3.6 m (apparent subsidence factor 0.64) reflects this sub-critical condition. The low seam gradient (1:10) does not necessitate a dip correction for the strain curves.

ATTACHED FIGURES

- Cross Section NSRF Line 3.00
- Cross Section NSRF Line 3.25
- Subsidence Profiles NSRF Line 3.00
- Subsidence Profiles NSRF Line 3.25

(See Enclosures 6 and 7)

46°25'00"N

80,000'W

40,000'W

60°10'W

Ciboux Island

Hertford Island

40,000'N

Cape Dauphin

46°20'00"N

Point Aconi

MAP 1

MAP 2

BRAS D'OR

ATLA

60°10'W

60°05'W

60°00'W

40,000'E

59°55'W

ATLANTIC OCEAN

MAP 2

MAP 3

MAP 4

MAP5

0.00'
60°05'W
60°00'W
40,000'E
59°55'W
59°50'W
80,000'E
46°25'00"N
N
LANTIC OCEAN
40,000'N
46°20'00"N
MAP 3
MAP 4
MAP5

GREAT BRAS D'OR

0.00'

46°15'00"N

ST. ANDREWS CHANNEL

46°10'00"N

NORTH SYDNEY

HARBOUR

SYDNEY

WEST ARM

SOUTH ARM

18 24 22 14 12 20 14 16 12 10 8 6 4 10 8 6 4 18

40,000'S

60°25'W

80,000'W

60°20'W

60°15'W

40,000'W

SYDNEY

60°10'W

NEW WATERFORD

INDIAN BAY

BRIDGEPORT BASIN

HARBOUR

SOUTH ARM

SYDNEY

GLACE BAY

DYSON POND

MAP5

0 1 2 3 4 5

MILES

SCALE 1"=1 MILE

BATHYMETRY OF STUDY AREA

CONTOUR INTERVAL 2m

NO TIDAL CORRECTIONS APPLIED

(MODIFIED AFTER JACQUES, WHITFORD AND ASSOCIATES LTD. 1984)

40,000'W

60°10'W

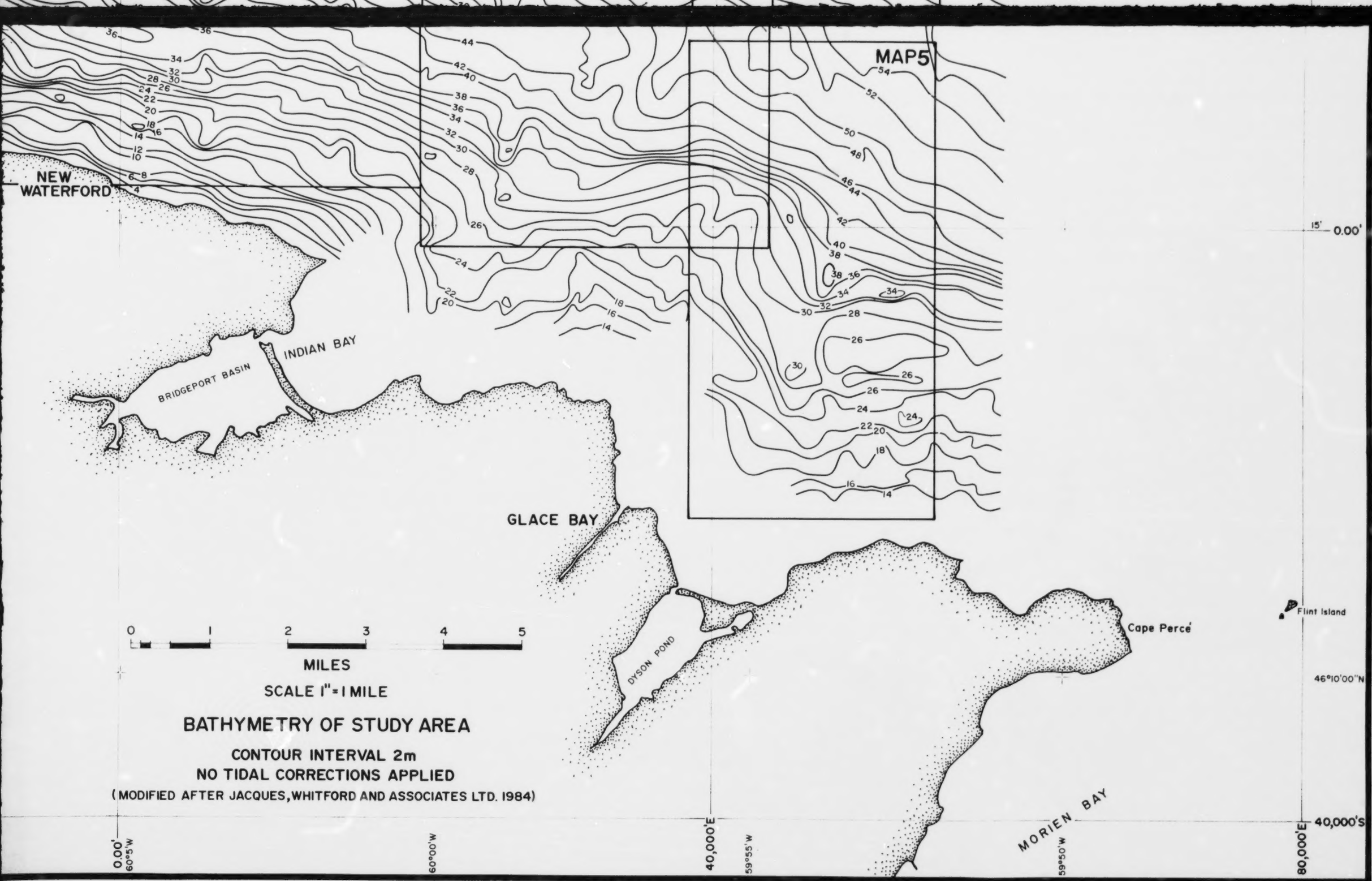
0.00'

60°5'W

60°00'W

40,000'E

59°55'W



BATHYMETRY OF STUDY AREA

CONTOUR INTERVAL 2m
NO TIDAL CORRECTIONS APPLIED
(MODIFIED AFTER JACQUES, WHITFORD AND ASSOCIATES LTD. 1984)

FIGURE 2

46°25'00"N

80,000'W

40,000'W

60°10'W

Ciboux Island

Hertford Island

40,000'N

MAP 1

ATLA

Cape Dauphin

Point Aconi

46°20'00"N

MAP 2

BRAS D'OR

60°10'W

60°05'W

0.00'

60°00'W

40,000'E

59°55'W

59°50'W

N

ATLANTIC OCEAN

OUTCROP ZONE

NORTHERN LIMIT OF STUDY AREA

MAP 2

MAP 3

MAP 4

MAP 5

0.00'
60°05'W

60°00'W

40,000'E

59°55'W

59°50'W

80,000'E

46°25'00"N

ANTIC OCEAN

40,000'N

46°20'00"N

OUTCROP ZONE

NORTHERN LIMIT OF STUDY AREA

MAP 3

MAP 4

MAP 5

GREAT BRAS D'OR

0.00' 46°15'00"N

ST. ANDREWS CHANNEL

46°10'00"N

40,000's

80,000'W

60°25'W

60°20'W

NORTH SYDNEY

HARBOUR

SYDNEY

WEST ARM

SOUTH ARM

60°15'W

40,000'W

SYDNEY

60°10'W

MAP 5

NEW WATERFORD

BRIDGEPORT BASIN

INDIAN BAY

GLACE BAY

DYSON POND

SYDNEY

MORIEN BA

0 1 2 3 4 5

MILES

SCALE 1"=1 MILE

ISOPACH OF SURFICIAL SEDIMENT

CONTOUR INTERVAL 4m

NO TIDAL CORRECTIONS APPLIED

(MODIFIED AFTER JACQUES, WHITFORD AND ASSOCIATES LTD 1984)

60°10'W

0.00'

60°5'W

60°00'W

40,000'E

59°55'W

59°50'W

MAP 5

NEW WATERFORD

BRIDGEPORT BASIN

INDIAN BAY

GLACE BAY

DYSON POND

Cape Percé

Flint Island

MORIEN BAY

0 1 2 3 4 5

MILES

SCALE 1"=1 MILE

ISOPACH OF SURFICIAL SEDIMENT

CONTOUR INTERVAL 4m

NO TIDAL CORRECTIONS APPLIED

(MODIFIED AFTER JACQUES, WHITFORD AND ASSOCIATES LTD-1984)

0.00'
60°5'W

60°00'W

40,000'E
59°55'W

59°50'W

80,000'E

15' 0.00'

46°10'00"N

40,000'S

FIGURE 3

ATLA

46°25'00"N

80,000'W

40,000'W

60°10'W

Ciboux Island

Hertford Island

40,000'N

FAULT ZONE (FROM OFFSHORE SEISMIC)

Cape Dauphin

46°20'00"N

MAP 1

Point Aconi

ZERO EDGE POST-MORIEN GROUP

POINT ACONI ANTICLINE

POINT ACONI SYNCLINE

MAP 2

FLORENCE SYNCLINE

BRAS D'OR

60°10'W

60°05'W

60°00'W

59°55'W

ATLANTIC OCEAN

MAP 1

ZERO EDGE
POST-MORIEN GROUP

NT ACONI
NTICLINE

POINT ACONI
SYNCLINE

FLORENCE SYNCLINE

NEW WATERFORD
NTICLINE

3500

3000

2500

2000

1500

MAP 2

MAP 3

MAP 4

0.00'
60°05'W

60°00'W

40,000'E

59°55'W

59°50'W

80,000'E

46°25'00"N

N

LANTIC OCEAN

40,000'N

46°20'00"N

3500

3000

MAP 3

2500

MAP4

MAP5

2000

1500

NEW WATERFORD
NTICLINE

GREAT BRAS D'OR

46°15'00"N

FLORENCE SYNC

SYDNEY HARBOUR SYNCLINE

NORTH SYDNEY

HARBOUR

SYDNEY

WEST ARM

SOUTH ARM

ST. ANDREWS CHANNEL

46°10'00"N

40,000'S

80,000'W

60°25'W

60°20'W

60°15'W

40,000'W

SYDNEY

60°10'W

FLORENCE SYN

2000

1500

1000

500

NEW WATERFORD ANTICLINE

NEW WATERFORD

SYDNEY HARBOUR SYNCLINE

BRIDGEPORT ANTICLINE

INDIAN BAY

BRIDGEPORT BASIN

GLACE BAY SYNCLINE

MAP

FAULT TRACE AT LEVEL OF HARBOUR SEAM

HARBOUR

SYDNEY

GLACE BAY

DYSON POND

SOUTH ARM

SYDNEY

0 1 2 3 4 5

MILES

SCALE 1"=1 MILE

DEPTH STRUCTURE ON HARBOUR SEAM AND MAJOR STRUCTURAL FEATURES OFFSHORE

(500ft CONTOUR INTERVAL)

(FROM FORGERON 1979 CITED IN BOEHNER AND GILES, 1986)

60°15'W

40,000'W

60°10'W

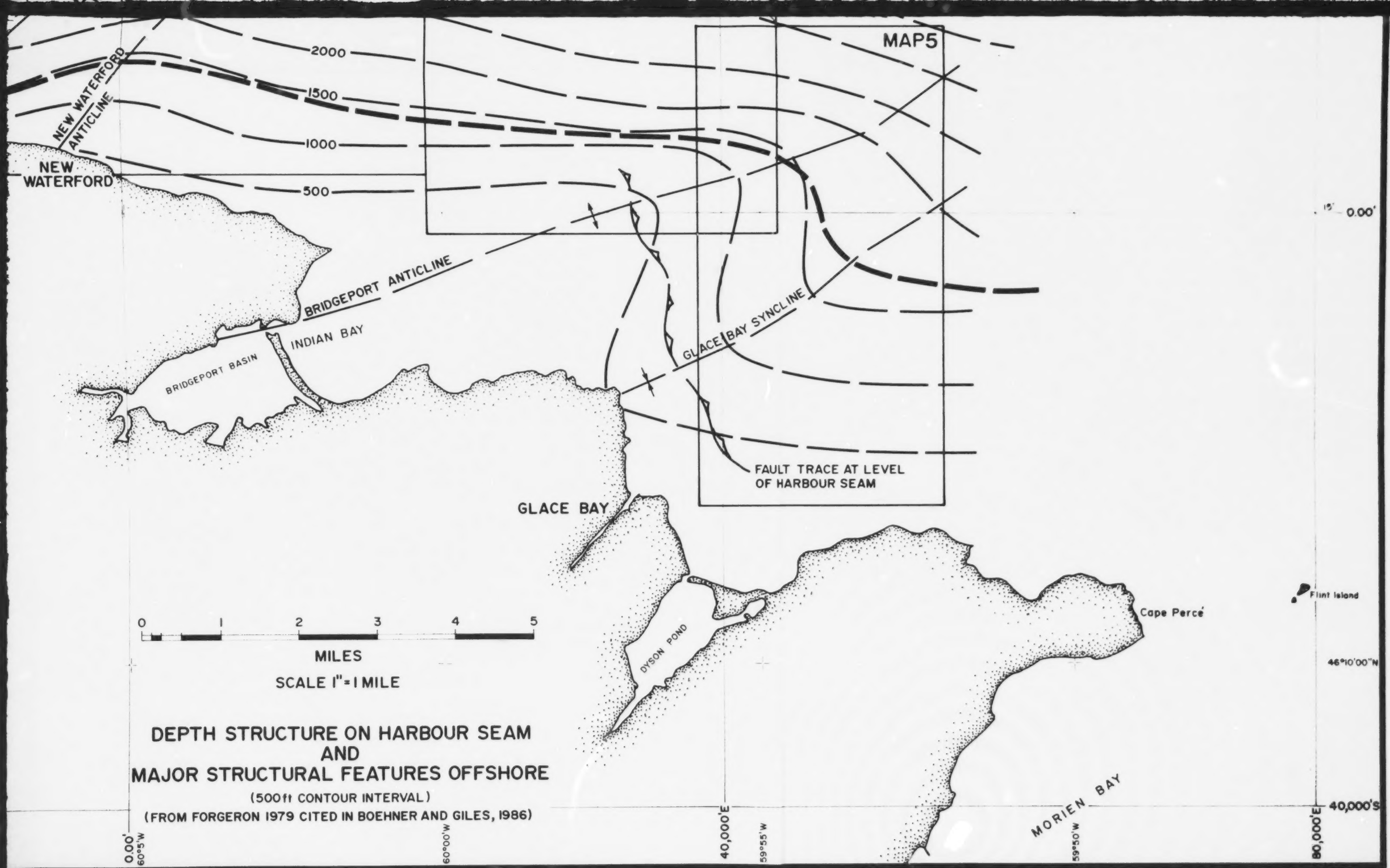
0.00'

60°5'W

60°00'W

40,000'E

59°55'W



DEPTH STRUCTURE ON HARBOUR SEAM AND MAJOR STRUCTURAL FEATURES OFFSHORE

(500ft CONTOUR INTERVAL)

(FROM FORGERON 1979 CITED IN BOEHNER AND GILES, 1986)

FIGURE 5

46°25'00"N

80,000'W

40,000'W

60°10'W

ATLA

Ciboux Island

Hertford Island

40,000'N

MAP 1

Point Aconi

Cape Dauphin

46°20'00"N

BRAS D'OR

MAP 2

No.6 co

60°10'W

0.00'
60°05'W

60°00'W

40,000'E
59°55'W

59°50'W

N

ATLANTIC OCEAN

MAP 2

MAP 3

MAP 4

MAP5

No.6 COLLIERY

0.00'
60°05'W

60°00'W

40,000'E

59°55'W

59°50'W

80,000'E

46°25'00"N

LANTIC OCEAN

40,000'N

46°20'00"N

MAP 3

MAP 4

MAP5

No.6 COLLIERY

GREAT BRAS D'OR

0°00' 46°15'00"N

ST. ANDREWS CHANNEL

46°10'00"N

40,000'S

60°25'W

80,000'W

60°20'W

NORTH SYDNEY

HARBOUR

SYDNEY

WEST ARM

60°15'W

40,000'W

SOUTH ARM

SYDNEY

60°10'W

No.6 CO

NE
WATE

MAP5

No.6 COLLIERY

NEW WATERFORD

No.1-A & 1-B COLLIERIES

INDIAN BAY

BRIDGEPORT BASIN

No.2 COLLIERY

No.4 COLLIERY

HARBOUR

GLACE BAY

DYSON POND

SOUTH ARM

SYDNEY

0 1 2 3 4 5

MILES

SCALE 1" = 1 MILE

DISTRIBUTION OF PHALEN COLLIERIES OFFSHORE

60°10'W

0.00'

60°5'W

60°00'W

40,000'E

59°55'W

MAP5

No.6 COLLIERY

NEW WATERFORD

No.1-A & 1-B COLLIERIES

INDIAN BAY

BRIDGEPORT BASIN

No.2 COLLIERY

No.4 COLLIERY

GLACE BAY

DYSON POND

Cape Percé

Flint Island

MORIEN BAY

15' 0.00'

46°10'00"N

0 1 2 3 4 5

MILES

SCALE 1" = 1 MILE

DISTRIBUTION OF PHALEN COLLIERIES OFFSHORE

0.00' 60°5'W

60°00'W

40,000'E

59°55'W

59°50'W

80,000'E

40,000'S

FIGURE 6

46°25'00"N

80,000'W

40,000'W

60°10'W

Ciboux Island

Hertford Island

40,000'N

MAP 1

PRINCE COLLIERY
HUB SEAM

Point Aconi

Cape Dauphin

46°20'00"N

BRAS D'OR

MAP 2

FLORENCE
COLLIERY

PRINCESS
COLLIERY

No.12
COLLIERY

ATLA

40,000'W

60°10'W

0.00'
60°05'W

60°00'W

40,000'E

59°55'W

MAP 1

ATLANTIC OCEAN

MAP 2

FLORENCE COLLIERY

PRINCESS COLLIERY

MAP 3

No.12 COLLIERY

LINGAN COLLIERY

MAP 4

No.26

0.00'
60°05'W

60°00'W

40,000'E

59°55'W

59°50'W

80,000'E

46°25'00"N

N

LANTIC OCEAN

40,000'N

46°20'00"N

MAP 3

MAP 4

MAP 5

.12
LLIERY

LINGAN
COLLIERY

No. 26

GREAT BRAS D'OR

0'00" 46°15'00"N

FLORENCE COLLIERY

PRINCESS COLLIERY

No.12 COLLIERY

WA

NORTH SYDNEY

HARBOUR

SYDNEY

ST. ANDREWS CHANNEL

46°10'00"N

WEST ARM

SOUTH ARM

40,000'S

60°25'W

80,000'W

60°20'W

60°15'W

40,000'W

SYDNEY

60°10'W

FLORENCE COLLIERY

PRINCESS COLLIERY

No.12 COLLIERY

No.14 COLLIERY

LINGAN COLLIERY

No.26 COLLIERY

MA

NEW WATERFORD

INDIAN BAY

BRIDGEPORT BASIN

No.20 COLLIERY

GLACE BAY

DYSON POND

NEY

HARBOUR

SYDNEY

SOUTH ARM

SYDNEY

0 1 2 3 4 5

MILES

SCALE 1" = 1 MILE

DISTRIBUTION OF HARBOUR AND HUB SEAM COLLIERIES OFFSHORE

60°15'W

40,000'W

60°10'W

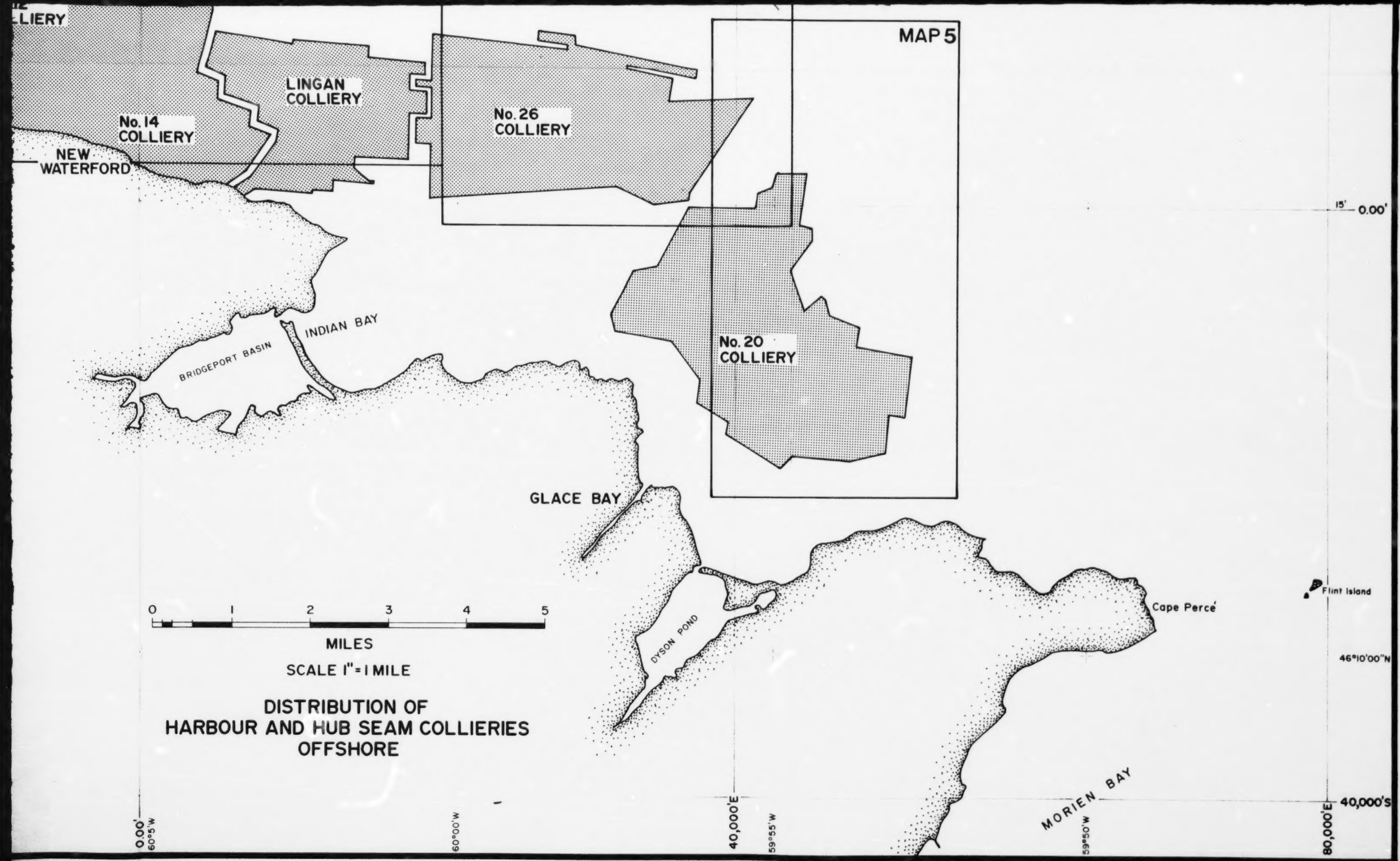
0.00'

60°5'W

60°00'W

40,000'E

59°55'W



DISTRIBUTION OF HARBOUR AND HUB SEAM COLLIERIES OFFSHORE

FIGURE 7